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Outcome after introduction of laparoscopic appendectomy in children: A cohort study

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ABSTRACT

Introduction: Acute appendicitis in children is common and the optimal treatment modality is still debated, even if recent data suggest that laparoscopic surgery may result in shorter postoperative length of stay without an increased number of complications. The aim of the study was to compare the outcome of open and laparoscopic appendectomies during a transition period.

Materials and methods: This was a retrospective cohort study with prospectively collected data. All patients who underwent an operation for suspected appendicitis at the Astrid Lindgren Children's Hospital in Stockholm between 2006 and 2010 were included in the study.

Results: 1745 children were included in this study, of whom 1010 had a laparoscopic intervention. There were no significant differences in the rate of postoperative abscesses, wound infections, readmissions or reoperations between the two groups. The median operating time was longer for laparoscopic appendectomy than for open appendectomy, 51 vs. 37 minutes ($p < 0.05$). The postoperative length of stay was similar in the two groups. A simple comparison between the groups suggested that laparoscopic appendectomy had a shorter median postoperative length of stay, 43 vs. 57 hours ($p < 0.05$). However, there was a trend in time for a shorter postoperative length of stay, and a trend for more of the procedures to be performed laparoscopically over time so on regression analysis, the apparent decrease in length of stay with laparoscopy could be ascribed to the general trend toward decreased length of stay over time, with no specific additional effect of laparoscopy.

Conclusions: Our data show no difference in outcome between open and laparoscopic surgery for acute appendicitis in children in regard of complications. The initial assumption that the patients treated with laparoscopic surgery had a shorter postoperative stay was not confirmed with linear regression, which showed that the assumed difference was due only to a trend toward shorter postoperative length of stay over time, regardless of the surgical intervention.

Acute appendicitis is a common disease in children and an appendectomy is the most common emergency operation performed in this population. For more than 100 years, an open appendectomy (OA) has been the treatment of choice for suspected appendicitis. The first appendectomy performed for the diagnosis of acute typhlitis was performed in Edinburgh by Robert Lawson Tait in 1880 [1] but it was McBurney who got his name immortalized after his paper in 1889 [2]. With improvements in anesthetics and later antibiotic treatment appendectomy evolved into routine practice, a further development came with the introduction of laparoscopic appendectomy (LA) in adults first presented by Semm in 1983 [3] and in children by Ure and coworkers in 1992 [4]. The first paper to present a benefit of LA over OA in children was presented by Gilchrist and coworkers in 1992 [5] but there has been no consensus in this debate ever since. Stronger support for the laparoscopic method was presented in a Cochrane review by Sauerland and coworkers in 2004 [6], concluding that "in those clinical settings where surgical expertise and equipment are available and affordable, we would generally recommend to use laparoscopy and LA in all patients with suspected appendicitis unless laparoscopy itself is contraindicated or not feasible". In 2006, Aziz and coworkers presented a metaanalysis [7] that included 23 studies with a total of 6477 patients. They showed that there were fewer postoperative complications after LA compared with OA. Based on these studies we decided to change from OA to LA in our department. To optimize the transition, we set up a strict protocol based on best available evidence at the time, together with prospective data collection of clinical data and outcomes.

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The preoperative diagnosis of acute appendicitis in children has been difficult and a high rate of negative appendectomies has been accepted to minimize the rate of perforations. A negative appendectomy rate in children of 20–30% has been reported [8], even if this number seems to decrease in recent years [8].

At our institution we have used imaging for diagnosis of acute appendicitis for more than ten years [8]. Virtually all patients that undergo surgery for suspected acute appendicitis have had an imaging diagnosis.

The aim of the study was to compare the outcome of open and laparoscopic appendectomies during a transition period.

1. Methods

This was a retrospective cohort study with prospectively collected data. All patients with the diagnosis of appendicitis, with any kind of appendectomy and all patients with an explorative laparoscopy were identified through the hospital discharge database and through our computerized theater log book. These patients were reviewed through our computerized notes system.

The study was conducted at the Department of Paediatric Surgery at the Karolinska University Hospital in Stockholm, Sweden. This department is the only tertiary referral center for pediatric surgery in the greater Stockholm area, 320–380 operations for suspected appendicitis are performed each year. OA was the procedure of choice until the autumn of 2007. At that point we designed a protocol for LA with the ambition to minimize the learning curve and to minimize the postoperative complications.

This protocol states the umbilical port to be introduced with an open technique according to Hasson [9]. We use a 12 mm Bluntport™ trocar (Covidien, USA) to accommodate a staple device and a specimen bag. Two 5 mm STEP™ trocars (Covidien, USA) are inserted in the lower left quadrant and suprapubically under direct vision. The base of the appendix is stapled with an Endo-GIA™ (Covidien, USA), 2.0 or 2.5 mm depending on the size of the appendix. If the abdominal cavity does not accommodate the Endo-GIA™ (Covidien, USA), endoloops are used. The mesoappendix is divided with either Endo-GIA™ (Covidien, USA) or monopolar hook diathermy. We advocate a liberal use of an Endo-Catch™ bag (Covidien, USA) in all cases, to avoid contamination from the area of division. Suction and irrigation is used according to surgeon's choice.

All patients who underwent an operation for suspected appendicitis in our department from January 2006 to December 2010 were included in this study. All patients had at least three months of follow up as described below. Baseline data as age, gender, temperature, CRP and white blood cell count were collected. Surgical modality, conversion, surgeon, operating time, time of surgery, time of discharge, surgeon's assessment of disease, histopathological assessment of disease, wound infection, presence of postoperative abscess and reoperation within three months were also collected. Since 2006 all patients as identified above have been included in our yearly performance report, hence most of the data presented in this paper has been retrieved on a yearly basis with at least three months follow up. A repeated search for the whole period was performed for this paper, for accuracy.

The final diagnosis was made in accordance with Carr [10] and thus on the histopathology finding described in Table 1. For the missing data in the open group ($n = 23/735$) the clinical assessment has been used. As we did not have a predefined clinical criteria for perforation these data may not be accurate. A routine sampling for white blood cell count and neutrophils was not in place during the first part of the series.

To be able to stratify patients for statistical purposes, the outcome parameters needed to be defined. We have defined a postoperative abscess as a localized fluid collection seen with imaging at least three days after the initial operation. Both an inserted drain and a drainage procedure without insertion of a drain were considered as drain treatment.

A reoperation was considered when the patient had to undergo a procedure by a surgeon either under general anesthesia. This included drainage of abscesses.

A wound infection was considered when a patient had been seen by a physician either as an inpatient, as an outpatient at the outpatient clinic or at the emergency room, or seen by the local general practitioners. Either pus or foul fluid had to been seen together with signs of inflammation. Antibiotic treatment is not necessary for the inclusion. The search has been made through the regional computerized notes database that includes all nonprivate general practitioners and all public hospitals in the region.

All data were prospectively put into our computerized notes database (Take Care™, GCM, Germany) and our computerized theater log

Table 1
A classification of acute appendicitis and the corresponding gross and microscopic appearances. From Carr NJ "The pathology of acute appendicitis" (2000), with permission.

Pattern	Gross	Microscopic	Significance
Acute intraluminal inflammation	No visible changes	Luminal accumulation of neutrophils only; no ulceration or transmural infiltrate	Probably none
Acute mucosal inflammation (catarrhal inflammation)	No visible changes	Neutrophils within mucosa and mucosal ulceration, with or without intraluminal neutrophils	May not be responsible for patient's symptoms; consider infective enteritis
Acute mucosal and submucosal inflammation	No visible changes	As above with neutrophils in submucosa	May not be responsible for patient's symptoms; consider infective enteritis
Suppurative acute appendicitis (phlegmonous appendicitis)	May be in apparent grossly; dull serosa; dilatation and congestion of surface vessels; fibrinopurulent serosal exudate in well-developed cases; appendix may be increased in diameter and/or dilated	Defined as neutrophilic infiltration of mucosa, submucosa, and muscularis propria; transmural inflammation; extensive ulceration, and intramural abscesses common; vascular thrombosis	An accepted cause of appendicitis-type symptoms
Gangrenous acute appendicitis (necrotizing acute appendicitis)	Appendiceal wall friable; purple, green, or black	Transmural inflammation with areas of necrosis; extensive mucosal ulceration	Perforation will complicate untreated gangrenous appendicitis
Periappendicitis	May appear normal or serosa may be dull, congested, and show an exudate	Inflammation of serosa and subserosa; infiltrate extends no further than outer muscularis propria	The cause probably lies outside the appendix
Increased mural eosinophils	No visible changes	>10 eosinophils/mm^2 in muscularis propria in the absence of any other changes	Unknown; possibly an early event in appendicitis, possibly of no significance; consider parasite or eosinophilic enteritis

Note: Before diagnosing acute intraluminal, mucosal, and submucosal inflammation, thorough sampling for histology to exclude inflammation of muscularis propria should be performed.

Table 2
Baseline characteristics for included patients.

	OA n = 735	LA n = 1010	
Age (years)	11.30 (1.93–15.00)	11.24 (2.06–14.99)	p = 0.411
Male gender (n)	446	604	p = 0.729
Temperature (°C) (n = 1730)	37.6 (35.6–40.3)	37.5 (35.5–40.1)	p = 0.218
CRP (mmol/l) (n = 1575)	23 (1–409)	22 (1–464)	p = 0.390
WBC (10^9/l) (n = 1186)	15.1 (4.1–43.0)	14.1 (3.3–36.7)	p = 0.005

book (Orbit 4™, Evry, Norway). As the initial database was incomplete, some data were retrospectively collected from these databases.

The computerized notes database was implemented in 2005 and we have access to prospectively collected data from 2006. The study period was determined to get an equal number of patients with each procedure.

Data are presented as frequencies or medians (range). Data were compared using Mann–Whitney U test and Fisher exact test where appropriate, and multiple linear regression using IBM SPSS Statistics version 21. $p < 0.05$ was considered as cutoff for statistical significance. The study is reported in conjunction with the STROBE guidelines [11].

2. Results

One thousand nine hundred and fourteen patients were found during our initial data search as described above. Patients with successful nonoperative treatment of suspected acute appendicitis (n = 62), patients discharged after successful nonoperative treatment of an appendix abscess/mass (n = 95) and patients who underwent an interval appendectomy (n = 12) were excluded from further analysis.

A total of 1745 patients had an operation for suspected acute appendicitis during the study period. This group constituted the study population. The basic characteristics for the included patients are presented in Table 2. The only significant difference between the two groups was a higher median white blood cell count in the patients treated with an OA. These data were missing for 41% of the open appendectomies and 25% of the laparoscopic appendectomies. In the open group with a WBC, the rate of gangrenous and perforated appendicitis was 59% and the same figure in the open group without a WBC was 47% (p = 0.001). The same was true for the laparoscopic group but to a lesser extent, 42% vs. 52%, (p = 0.005).

The yearly proportion of patients that underwent a laparoscopic appendectomy from 2006 to 2010 was 2.9%, 22.5%, 85.1%, 80.5% and 95.1%, respectively.

The postoperative time in hospital was longer for the patients who had an OA compared with the patients who had an LA, 57 (10–580) vs. 43 (10–583) hours ($p < 0.05$). However, there was a trend toward increasing use of laparoscopy over the period of the study, so we were concerned that the apparent benefit of laparoscopy in terms of hospital stay in fact represented a general trend toward decreased length of hospital stay during the study (Fig. 1). We therefore performed a multiple linear regression. The dependent variable was $\log_{10}$ (hospital stay in hours) as hospital stay was not normally distributed and a log transformation yielded data that were approximately normally distributed. The independent variables examined were; gender, age, and interaction terms for open or laparoscopic operation × years since start of study. The results of the multiple linear regression analysis are shown in Table 3. Hence there was a significant age effect, with older patients staying in hospital −0.02 $\log_{10}$ hours ($p < 0.05$), and a significant gender effect, with females having a significantly longer hospital stay (+0.049 $\log_{10}$ (length of hospital stay in hours); $p < 0.05$). For both laparoscopic and open operations, there was a significant decrease in length of hospital stay during the period of study, with the magnitude of decrease exactly the same for each type of operation (i.e. a 0.043 decrease in $\log_{10}$ (length of hospital stay in hours) for each year since the start of study ($p < 0.05$ for each)). As it is difficult to consider the magnitude of these changes in $\log_{10}$ (hospital stay in hours), we have shown an example of these trends over time for a 10-year-old boy in 1. 1. The trends over time are almost identical for open and laparoscopic operations, with wider 95% confidence intervals for open surgery, owing to the lower number of open operations.

Table 3
Multiple linear regression analysis of the effects of age, gender, OA and LA over time on length of hospital stay.

	Unstandardized Coefficients		p Value	95.0% Confidence Interval for B	
	B	Standard Error		Lower Bound	Upper Bound
(Constant)	2.034	.031	<0.0005	1.972	2.095
Age	−.020	.002	<0.0005	−.024	−.015
Gender	.049	.015	=0.001	.019	.078
Lap × time	−.043	.005	<0.0005	−.053	−.033
Open × time	−.043	.010	<0.0005	−.062	−.024

The dependent variable was $\log_{10}$ (hospital stay in hours).

As treatment of acute appendicitis is highly protocol driven in terms of antibiotic administration etc., we also repeated this analysis considering only those patients in whom a difference in hospital stay might be possible because of the type of surgery performed; i.e. those patients with operative findings of either a noninflamed or phlegmonous appendix. The results were almost identical, i.e. there was a significant decrease in length of hospital stay for both open and laparoscopic operated patients of the same magnitude (0.044 decrease in $\log_{10}$ (length of hospital stay in hours) for each year since study start). Taken together, these data strongly suggest that the apparent decrease

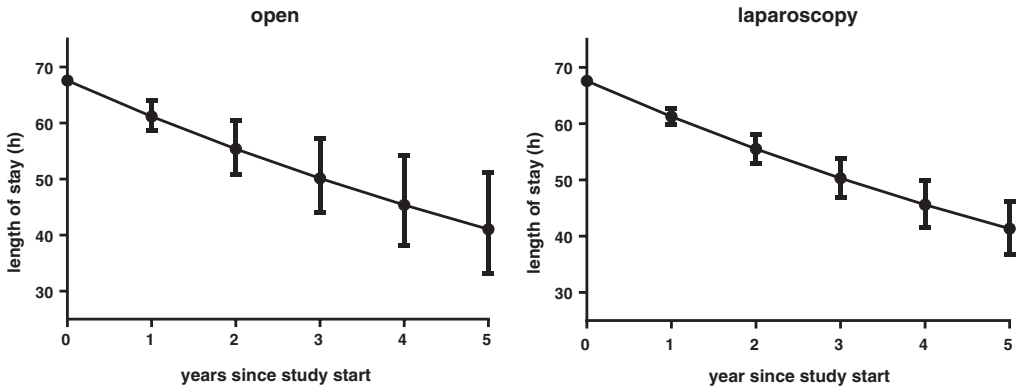

Fig. 1. Effects of time and laparoscopic/open operation on length of hospital stay. Data are calculated from the multiple regression analysis in Table 2, for a 10 year old boy. Data are given with 95% confidence intervals.

Table 4
Complications after open and laparoscopic appendectomy.

	OA n = 735	LA n = 1010	
Wound infection	9 (1.2%)	25 (2.5%)	p = 0.078
Abscess formation	35 (4.8%)	36 (3.6%)	p = 0.221
Reoperation	20 (2.7%)	26 (2.6%)	p = 0.880
Readmission	42 (5.7%)	37 (3.7%)	p = 0.047

in length of hospital stay in laparoscopic vs. open operated patients is entirely because of a general trend in decreased hospital stay rather than anything specific to the operative method.

There were no significant differences in the rate of postoperative abscesses, wound infections or reoperations between the two groups, as seen in Table 4. There were more readmissions in the open group. There were no differences in the final histopathological diagnoses in the two groups as seen in Table 5. Histopathology diagnosis was not obtained in 23 patients after open appendectomy as this was not mandatory in the earliest part of the study. In the open group, the "other" cases were three cases of carcinoid tumors, one granulomatous appendicitis and one chronic inflammation. In the laparoscopic group the "other" cases were also three carcinoid tumors and two cases of chronic inflammation. None of the carcinoids were suspected at the preoperative imaging.

The operative time was longer for LA than for OA, 51 (11–307) vs. 37 (11–185) minutes in the whole group ($p < 0.05$). There was a significant ($p < 0.05$) decrease in operative time from study start for both the laparoscopic (0.014 $\log_{10}$ minutes operative time per year since study start) and open (0.016 $\log_{10}$ minutes operative time per year since study start) groups.

For LA, the median operating times for individual surgeons were between 31 minutes (99 operations) and 73 minutes (59 operations).

3. Discussion

This is a large single center cohort of all patients who had surgery for acute appendicitis from January 2006 to December 2010. In our study we assessed the outcome complications by the intervention open or laparoscopic appendectomy. The groups were similar at baseline apart from a slightly higher white blood cell count in the open group. That may constitute a true difference but is more likely because of the fact that this test was less common in the early part of the series when most of the open operations were made. This is supported by the fact that there was a tendency of more severe cases with white blood cell count in the open group compared to the laparoscopic group. There was no difference in any assessed complications. The operating time was longer for LA than for OA but there was a large intersurgeon difference in operating time supporting the need for training and continuous assessment of individual surgeons to decrease operating times.

We show that the patients who had an LA had a shorter postoperative stay than patients who had an OA but that this is related to a change of management over time and not because of the surgical modality. Interestingly, there has been no change in the treatment protocol for patients after an appendectomy during the trial period. So, we suggest that introduction of laparoscopic appendectomy showed that the patients could be discharged early but that this was true also for the patients treated with an OA.

Table 5
Histopathological diagnosis.

	OA n = 712	LA n = 1010	
No inflammation	19 (2.7%)	39 (3.9%)	p = 0.165
Phlegmonous	307 (43.2%)	464 (45.9%)	p = 0.273
Gangrenous	214 (30.1%)	298 (29.5%)	p = 0.909
Perforated	167 (23.5%)	203 (20.1%)	p = 0.095
Other	5 (0.7%)	5 (0.5%)	p = 0.587

One significant aspect of this study is that the two parts of the cohort are different in time. This is best shown by the fact that the postoperative time in hospital is shorter assessed by basic statistics but was shown to be dependent on time rather than on surgical modality. This finding has implications for other studies, which compare laparoscopic with open techniques. Even though the patients operated on laparoscopically and open were operated in the same time period, a simple statistical comparison may lead to erroneous conclusions unless other factors are carefully considered. One strength of our study is that the large number of patients operated allowed us to analyze trends over time as well as surgical modality.

Previous metaanalyses have presented clear benefits for LA over OA [7,12,13] in regard of wound infections and length of stay. In the Aziz paper [7], the postoperative wound infection rate after OA and LA was 5.0% vs. 1.5%. In our series the same numbers were 1.2% vs. 2.5%. A recent paper by Andersson in 2014 [14] presents data on all open and laparoscopic appendectomies in Sweden 1992–2008, adults as well as children. Here, the hospital stay was 0.06 days shorter after a laparoscopic operation (2.86 vs. 2.92 $p < 0.001$). In regard of complications, Andersson presents a lower rate of wound infections but a higher rate of deep abdominal infections in the laparoscopic group.

In this cohort study, we used data collected at the time of intervention but as there was no prospectively designed data form some data were not completely collected. Hence, there were a number of patients in the open group who had no histopathological diagnosis, as this was not mandatory in the early part of the series. There was also an uneven distribution in the proportion of white blood cell count samples taken as this was not as common in the earlier years.

As all collected data were taken from databases with prospective input there was no information bias because of retrospective data collection.

In conclusion, a swift transit from OA to LA was safe and feasible. The learning process did not increase complications despite the fact that the majority of surgeons were novices in laparoscopic surgery at the start of this study. The initial operative time was longer, but decreasing over time. The postoperative stay was shorter in 2010 than in 2006 but not because of the surgical modality.

As this study was conducted in a large tertiary center treating all patients within the greater Stockholm area, and involving surgeons at all different levels of expertise the results should be transferable to other centers with similar demographics.

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