RESEARCH PAPER

Comparison of Open and Laparoscopic Appendectomy in Children: A 5-year Single Center Experience

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Objective: To compare the outcomes of treatment in children with acute appendicitis between laparoscopic and open surgical approaches.

Design: Retrospective study.

Setting: Division of Pediatric Surgery at a tertiary-care hospital in Croatia between January 2012 to December 2016.

Patients: 834 children [median (IQR) age 13 (11,15)] who underwent appendectomy; 301 in the laparoscopic group and 533 in the open group.

Main outcome measures: Postoperative complications, duration of hospitalization, re-operation, and the quantity of analgesics used.

Results: The median length of hospital stay was 3 days in laparoscopic group compared to 6 days in open group (P<0.001). The amount of analgesics used was lower in patients with laparoscopic appendectomy compared to patients who underwent open procedure (P=0.042). Significantly higher number of wound infections was recorded in the open group (n=21; 3.9%) compared to laparoscopic group (n=3; 1%) (P=0.014). The frequency of re-operation in both groups was equal (1.3%). The median duration of surgery was shorter in the group of patients with laparoscopic appendectomy compared to the open approach (30 *vs*. 45 min; P<0.001). In five-year period, the proportion of laparoscopic appendectomies increased by 21.5%.

Conclusion: Laparoscopic appendectomy was safe and effective in children. Advantages of laparoscopic approach were shorter hospital stay, lower number of wound infections and lower usage of analgesics.

Keywords: *Appendicitis, Complications, Surgery, Treatment.*

Acute appendicitis is the most common surgical condition in children and has a high rate of morbidity in children [1]. There are two possible operative approaches: laparoscopic, and the classic approach, *i.e.* open appendectomy [1]. Nowadays, three quarters of the appendices are removed laparoscopically [2]; however, the efficacy and superiority of the laparoscopic appendectomy has been under debate. The data favor laparoscopic appendectomy resulting in shortened hospital stay, lesser postoperative pain, quicker overall recovery, and lower rates of wound infections [3,4]. Laparoscopic appendectomy over open appendectomy also benefits in a better visualization and identification of other abdominal pathologies that can mimic acute appendicitis [1,2]. However, several retrospective investigations, randomized studies and meta-analyses which compared the open and laparoscopic appendectomy have yielded mixed results [3-7].

We compared treatment outcomes of laparoscopic versus open approach in children with acute appendicitis within a five-year period.

METHODS

Data of all children and adolescents (age 0-18 y) who underwent appendectomy because of suspected acute appendicitis between January 1, 2012 and December 31, 2016 in the Department of Pediatric Surgery, at University Hospital of Split, Croatia, were included in the study. Ethics Committee of University Hospital of Split approved the study. Exclusion criteria were: patients with incomplete medical documentation and the patients where another pathological cause was found during the exploration of abdominal cavity. The case records of all included children were retrospectively reviewed. Based on approach used for appendectomy, the patients were divided into two groups: the first group included patients who underwent a laparoscopic appendectomy, while the

second group included patients who underwent open appendectomy. The choice of procedure was based on operating surgeon preference. All surgeries were performed in emergency settings. The following parameters were recorded for each patient: demographic data (age, sex, Body mass index); preoperational laboratory tests (white blood cell count, C-reactive protein); clinical data (duration of symptoms, body temperature and local findings); treatment outcomes (duration of surgery, hospital stay, number of re-operations); intraoperative and postoperative complications; and need for analgesia (quantity of analgesics). Preoperatively, all patients underwent a clinical examination and laboratory analysis. ALVARADO score and Pediatric appendicitis score were calculated in all patients [8]. In most of the patients, abdominal ultrasonography was performed.

Open appendectomy: The patient was placed in supine position. Modified Lanz incision was used. After opening of the peritoneum, appendix was identified and pulled through the incision. Mesoappendix was skeletonized in ante-grade fashion from tip to base using absorbable suture (Vycril 3/0, Ethicon, Cincinnati, Ohio, USA). The appendix was tied at the base and removed. Exposed mucosa at the stump was cauterized. Stump inversion was performed by string suture-knot.

Laparoscopic appendectomy: The patient was placed in supine position, combined with the Trendelenburg position and left lateral position. A Veress needle was introduced through 5-mm supraumbilical incision and CO_2 was insufflated at a pressure of 8-12 mm Hg depending on patients' age and bodyweight. After achieving pneumoperitoneum through the same incision, 5-mm trocar was introduced and a 5-mm scope was used. Laparoscopic appendectomy was performed using a three-trocar technique with a combination of 5- and 10-mm trocars. The mesoappendix was dissected with either a harmonic scalpel (Ultracision, Ethicon Endo-surgery, Cincinnati, OH, USA) or thermal fusion technology (MiSeal, Microline, Beverly, Massachusetts, USA). Appendiceal base was secured using endoloop (Vycril Endoloop-0, Ethicon Endo-surgery, Cincinnati, Ohio, USA) or polymeric clips (Ligating Clips XL, Grena, Brentford, UK). Each specimen was retrieved inside a disposable specimen retrieval bag (Ecosac EMP 70, Espiner Medical Ltd.) through 10-mm trocar.

Antibiotics were used only in cases of perforated appendicitis, or in cases when intraoperative perforation occurred. The combination of gentamicin (3-6 mg/kg) and metronidazole (7.5 mg/kg) was most commonly used.

In postoperative period, oral or intravenous analgesics were used only on patient demand. Paracetamol (10-15 mg/kg) or ibuprofen (10 mg/kg) were usually used. Pain assessments, including patients' self-reported pain intensity scores, was obtained and documented at least once during every 12-hour shift, before pain management interventions, and within one hour after the administration of an analgesic. All documented pain intensity scores were extracted from the patients' medical records. Substantial pain was defined as mean pain scores greater than four on a scale of zero to 10 in two or more of the six-hour postoperative time intervals.

Criteria for discharge in children with uncomplicated appendicitis included the adequate postoperative intake and pain control. Similarly, children with complicated appendicitis were considered ready for discharge once they had met the same criteria but also had resolution of fever and return of normal white blood cell count.

The outcome measures for comparison were the postoperative complications, duration of hospitalization, percentage or re-operations, and the quantity of analgesics demanded by the patients. The intraoperative complications included access-related complications such as organ lesions, thermal damage of intra-abdominal organs, and intraperitoneal bleeding. Postoperative complications included wound infection, bleeding, bowel obstruction, postoperative ileus and abscess formation. The duration of surgery and the patients' subjective assessment of fitness after the operation were also compared in two groups.

Statistical analysis: The data were analyzed using the Microsoft Excel for Windows Version 11.0 (Microsoft Corporation) and SPSS 19.0 (IBM Corp, Armonk, NY) software programs. Distributions of quantitative data were described by means and standard deviations, or medians and ranges, whereas absolute rates and percentages were used to describe categorical data. Differences in median values of quantitative variables between the groups of patients were tested with Mann–Whitney U test. The chi-square test was used for the statistical analysis of the categorical data. All values of $P<0.05$ were considered to indicate statistical significance.

RESULTS

A total number of 855 patients underwent appendectomy for suspected appendicitis during the study period. Twelve patients were excluded from the study because they met one or more exclusion criteria. Finally, 834 (62% males) patients with median age of 13 (IQR 11, 15) years, and median BMI of 20 (IQR 18, 22) kg/m^2 were included in

the study. Laparoscopic appendectomy was performed in 36% (*n*=316) and open appendectomy in 64% (*n*=533) patients.

An analysis of the patient data showed that there was a significant statistical difference between the groups with respect to age (*P*=0.025), body temperature (*P*<0.001) and vomiting frequency (*P*=0.012). There were no significant differences between the two groups regarding demographic data (age and BMI), preoperative laboratory values (white blood cell count and C-reactive protein level), or clinical data (duration of symptoms, nausea and local clinical findings) (***Table* I**).

The median duration of surgery was 15 minutes shorter in laparoscopic group (*P*<0.001) (***Table* II**). The median hospital stay was 3 days shorter in laparoscopic group compared to open group (*P*<0.001) (***Table* II**). Among the 834 patients included in the study, 41 (4.9%) postoperative complications were recorded (*P*=0.031); 9 (1%) in laparoscopic and 31 (6%) in open group (***Table* II**). Wound infection rate was higher in patients who underwent open appendectomy in relation to those who underwent a laparoscopic appendectomy (*P*=0.014). The frequency of other complications (intra-abdominal abscess, dehiscence of appendix stump, ileus and operative incision bleeding) was comparable in both groups (***Table* III**). Most complications were treated conservatively. A total of 11 patients required re-operation, 4 (1.3%) patients in the laparoscopic group and 7 (1.3%) patients in the open group.

TABLE I BASELINE CHARACTERISTICS OF PATIENTS UNDERGOINING APPENDECTOMY

	Laparoscopic method (n=301)	*Open method (n=533)*
Age, y	13 (13, 15)	12 (9, 15)
Male sex, *n* (%)	175 (58)	343 (64)
BMI, kg/m^2	20 (18, 22)	19 (17, 22)
*Leukocytes (x10^9/L)	14.3 (11.3, 17.5)	14.6 (11.3, 18.4)
#CRP (mg/dL)	22.4 (6.2, 54.9)	23.9 (5.6; 55.6)
Duration of symptoms (h)	20 (12, 30)	24(17, 48)
*Body temperature, ºC	37.3 (37.0, 37.7)	37.1 (36.8, 37.5)
Nausea, *n* (%)	247 (82)	438 (82)
Vomiting, *n* (%)	155 (52)	212 (42)
Pain migration to lower right quadrant of abdomen, *n* (%)	241(80)	431(81)
Localized pain, *n* (%)	244(81)	451(85)

*All values in median (IQR) unless stated otherwise; *P<0.001; #Preoperative values.*

TABLE II TREATMENT OUTCOMES OF CHILDREN WHO UNDERWENT APPENDECTOMY

	Laparoscopic method (n=301)	*Open method (n=533)*
Treatment outcomes		
*#Duration of surgery, min	30 (25,45)	45 (40,60)
#*Hospital stay, d	3 (3,4)	6 (6,8)
Reoperation, *n* (%)	4 (1.3)	7 (1.3)
‡Complications, *n* (%)	9 (1)	32 (6)
*Quantity of analgesics, *n*	1 (0,3)	1 (1,2)

**Values in median (IQR); #P<0.001; ‡P<0.05.*

Median quantity of analgesics used in postoperative period was similar in both groups; though, somewhat lower quantity of analgesics was used by patients who underwent laparoscopic appendectomy in relation to the patients who underwent open appendectomy (*P*=0.042) (***Table* II**).

A histopathological analysis revealed a positive diagnosis of appendicitis in 768 patients (96%). The analysis of all of the appendectomies in 5-year period showed an increased frequency of laparoscopic appendectomy from 28.9% to 50.4%, whereas a decline in open appendectomies from 71.1% to 49.6% was recorded (***Fig.* 1**).

DISCUSSION

In this retrospective comparative study, we observed that laparoscopic appendectomy in children was a safe and effective surgical procedure with shorter duration of surgery and hospital stay, and lesser frequency of complications and post-operative incisional pain. Our results are in agreement with few other studies and meta-analyses [3-7]. Our study also documented that the trend of operative procedure in treating acute appendicitis has shifted in favor of laparoscopic appendectomy at our

TABLE III COMPARISON OF THE POSTOPERATIVE COMPLICATIONS DEPENDING ON THE SURGICAL APPROACH

Complication (n,%)	*Laparoscopic method (n=301)*	*Open method (n=533)*
#Wound infection	3 (1)	21 (3.9)
Intra-abdominal abscess	5 (1.7)	9 (1.7)
‡Dehiscence	1 (0.3)	1 (0.2)
Ileus	0	2 (0.4)
*Bleeding incision	1 (0.3)	0
#Total	10 (3.3)	33 (6.2)

*#P<0.05; *from operative incision; ‡of appendiceal stump.*

WHAT IS ALREADY KNOWN?

- Open and laparoscopic appendectomy are both safe but there has been a controversy about which surgical procedure is the most appropriate in children.

WHAT THIS STUDY ADDS?

- Laparoscopic surgery for acute appendicitis in chidren seems to be superior to open appendectomy in terms of length of hospital stay, rate of postoperative wound infections and postoperative pain.
- Duration of surgery in hands of experienced laparoscopic surgery is shorter compared to open surgery.

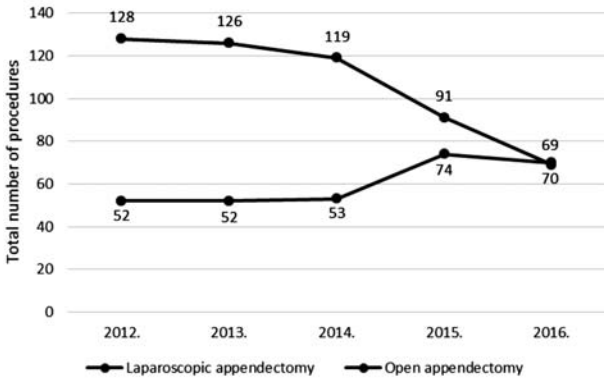

FIG. 1 *Trend in use of surgical approach for appendectomy*.

institution. This concurs with the earlier observations by Masoomi, *et al*. [5].

Retrospective nature and non-randomized comparison are the main limitations of this study. As a higher proportion of cases of laparoscopic appendectomy belonged to second half of our study period, it is possible that some parameters improved because of general improvement in healthcare services rather than because of the method of surgery.

The length of hospitalization is an important factor having a direct influence on patient management. The results of many published studies also have shown that the length of hospitalization for the patients who underwent laparoscopic appendectomy was significantly shorter [5,7,9-12]. Postoperative complications are considered the best method for evaluation for the safety of a particular procedure. The most common complications of appendectomy are: wound infection, intra-abdominal abscess, post-operative ileus and bleeding [9]. The results of the meta-analysis performed by Wei, *et al*. [9] have shown a lower complication rate in the patients who underwent laparoscopic appendectomy. The rate of infection is lower in laparoscopy because the inflamed appendix is pulled through a trocar, thus not touching the abdominal wall. Visibility and magnification are much better during laparoscopic procedure. Lower invasiveness of the laparoscopic procedure, causing less damage to intestinal serosa, lowers the adhesions-caused ileus rates [9]. Our study showed a statistically significant lower rate of wound infection in patients who underwent laparoscopic appendectomy. The frequency of other complications (intra-abdominal abscess, appendix stump dehiscence, ileus and incision bleeding) was similar in both groups. Similar results have been observed in other published studies [5,9-11,13-15].

Most of studies recorded a longer duration of surgery with laparoscopic approach than with open appendectomy [7,9-11,15] whereas few studies reported similar or even shorter operating time with laparoscopic approach [12-14]. Our study showed that the operating time of the laparoscopic procedure was 15 minutes shorter than that of open appendectomy. Better visualization during the laparoscopic approach and the expertise of the operating surgeon are possible explanations for shorter length of laparoscopic procedure. Also, device used for skeletonization of mesoappendix and technique of securing of the appendiceal stump in laparoscopic appendectomy may affect operating time [2,16-20]. The incidence of thermal related injuries of the surrounding tissues is significantly higher in laparoscopic surgery compared to the open surgery, although in our study no case of thermal injury was recorded [16,18-20]. Less postoperative pain, higher quality of life and less amount of used analgesics is usually reported in patients who underwent laparoscopic appendectomy [9,21]. In our study, the usage of analgesics was similar in both groups; although, lower quantity of analgesics was used in laparoscopic appendectomy patients.

In conclusion, laparoscopic appendectomy seems to be a safe and effective procedure for children having appendicitis. It results in less postoperative pain, and significantly reduces hospital stay and postoperative wound infection. Duration of the surgery in hands of

experienced laparoscopic surgeon also may be lower in laparoscopic appendectomy compared to open procedure.

Contributors: ZP: concept and design of the study, analyzed the data; MB: collected the data and helped in data analysis and drafting of the manuscript; TS: performed literature review and drafted the manuscript; MJ: collected the data, drafted the manuscript and revised manuscript critically; TPP: performed statistical analysis of the data and contributed to manuscript writing; IJ: supervised and revised manuscript critically for important intellectual content. All authors approved the final version of manuscript and agree to be accountable for authenticity and integrity of the work.

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