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Laparoscopic Appendectomy in Children After the Learning Curve

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ABSTRACT

Objectives: Despite its increasing popularity, several recent studies comparing laparoscopic appendectomy (LA) with open appendectomy (OA) in children have failed to demonstrate significant improvements in patient outcomes. Many series include the "learning curve," wherein surgeons inexperienced with laparoscopic techniques compare their results with results with OA with its extensive history. This study was designed to investigate outcomes in pediatric appendectomy patients managed by surgeons with extensive laparoscopic experience.

Methods: We preformed a retrospective review of 197 consecutive children undergoing appendectomy for presumed acute appendicitis from January 2002 through May 2004 at a university-affiliated community hospital by pediatric and general surgeons with extensive laparoscopic surgical experience.

Results: The study included 117 patients who underwent LA and 80 who underwent OA. Of 122 acute appendicitis cases, mean operating times were 47 minutes (LA) and 48 minutes (OA). The LA group (n=71) had a faster return to full diet (17.6 h vs. 28.6 h, P=0.0008), and shorter postoperative length of stay (LOS) (1.06 d vs. 1.66 d, P<0.0001) compared with the OA group (n = 51). Complication rates, time on intravenous (IV) antibiotics, and IV opiates were similar among the 2 groups. Complicated appendicitis cases (LA, n=34; OA, n=26) were similar with regard to LOS, return to normal bowel function, complication rate and time on IV antibiotics and opiates, but was associated with an increased operation time (LA, 65 min; OA, 51 min, P=0.02).

Conclusions: Following the completion of the laparoscopic surgery learning curve, LA has a comparable operation time and results in a decreased postoperative LOS, and faster return to normal bowel function compared with OA in children with acute nongangrenous, nonperforated appendicitis.

Key Words: Laparoscopic appendectomy, Open appendectomy, Learning curve, Children.

INTRODUCTION

Although first reported in adult patients in the 1980s, modern video-assisted laparoscopic appendectomy (LA) continues to be routinely used by only a small fraction of pediatric surgeons. United States discharge data from 2000 from 30 freestanding children's hospitals revealed only 31% of pediatric appendectomies were performed laparoscopically.[1] An American Pediatric Surgical Association (APSA) survey published in June 2004 showed only 31% of pediatric surgeons perform LA frequently or always, and 39% of them do them rarely or never.[2]

Many series **(Table 1)**[3–20] have failed to demonstrate any specific advantages to the newer laparoscopic technique compared with open appendectomy (OA). These reports have been criticized, however, for including the surgical learning curve, wherein surgeons inexperienced with laparoscopic techniques compare their results with results for OA, with its extensive history, potentially resulting in misleading conclusions.[7,8,14,15] This study was designed to investigate outcomes in a series of pediatric appendectomy patients managed by surgeons with extensive laparoscopic experience.

METHODS

Following Institutional Review Board approval, a retrospective medical record review of 197 consecutive children from May 2002 to January 2004 at a university-affiliated private teaching hospital was performed. All patients had a preoperative diagnosis of acute appendicitis. Patients received all pre-, intra-, and postoperative care by the same emergency department staff, anesthesiologists, surgical residents, and nurses.

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Table 1.
Pediatric Laparoscopic Versus Open Appendectomy Comparative Series

Author	Institution State, Country	No. of Patients		Operative Time (min)		Postoperative LOS (d)		Complications (%)	
		OA	LA*	OA	LA*†	OA	LA*†	OA	LA*†
Varlet[3]	France	203	200	55	72‡	6.4	4	10.8	1
Plattner[4]§	France	92	58	43	63	No difference		OA>LA	
Horwitz[5]	Texas, USA	22	27	No difference		No difference		18	52
Kokoska[6]	Missouri, USA	464	126	Not reported		2.4	1.7	Not reported	
Canty[7]	California, USA	173	955	No difference		3	2	No difference	
Foulds[8]	New Zealand	461	106	40	59	2.4	2	N	
Lintula[9]	Finland	31	30	No difference		No difference		10	3
Lavonius[10]	Finland	20	23	No difference		No difference		No difference	
Little[11]	Texas, USA	44	44	51	75	No difference		No difference	
Meguerditchian[12]	Canada	262	126	40.6	45.7	2.9	2.4	No difference	
Lee[13]	Taiwan	59	54	No difference		4.69	3.45	No difference	
Ikeda[14]	Japan	47	53	59	88	9	6	No difference	
Wei[15]	Taiwan	17	83	No difference		5.33	2.55	No difference	
Lintula[16]	Finland	44	43	31	42	3	2.8	11	4.7
Vernon[17]	Alabama, USA	95	105	No difference		No difference		Not reported	
Oka[18]	Rhode Island, USA	376	141	No difference		No difference		No difference	
Vegunta[19]	Illinois, USA	34.5	57	34.5	57	2.5	2	29	17
Tirabassi[20]§	Massachusetts, USA	54	11	No difference		No difference		Not reported	

*OA = open appendectomy; LA = laparoscopic appendectomy; LOS = Length of stay.

†No difference indicates that outcomes measured did not reach statistical significance.

‡Time was defined as "time of general anesthesia."

§Studies were for complicated appendicitis cases only.

Data collected included demographics (age, sex, insurance status); preoperative data, including temperature, white blood cell count, wait until surgical treatment, preoperative imaging studies performed and results; operating time; and surgical technique performed (LA vs. OA). Wait until surgical treatment was defined as time from initial evaluation by emergency department physicians to the initial operative skin incision. Operating time was defined as the time from initial skin incision to final skin suture. Surgical technique (LA vs. OA) was determined by the responsible operating surgeon.

Postoperative variables collected include postoperative length of stay (LOS), time on intravenous (IV) antibiotics and opiates, time to resumption of full diet, placement of drains, complications, histology of appendix, and total hospital charges. Any other pathology that was found upon exploration of the abdomen or pelvis during surgery was noted.

All pathology reports were interpreted by attending pathologists. Complicated appendicitis was defined as either gangrenous appendicitis or the presence of perforation as noted in either the operative report or based on the histology of the pathological specimen.

Results were analyzed using general linear models for continuous variables. Chi-squared P values were used for unordered discrete or dichotomous variables, and Mantel-Haenszel chi-squared P values were used for ordered discrete variables. Statistical significance was established at an alpha value <0.05.

RESULTS

From January 2002 through May 2004, 197 appendectomies were performed in children, with a preoperative diagnosis of appendicitis **(Figure 1)**. Fifty-nine percent of the operations (n=117) were laparoscopic appendectomies (LA), and 41% (n=80) were open appendectomies (OA). Of the 197 patients, 122 (62%) presented with acute, nongangrenous, nonperforated appendicitis, with 71 LAs (58%) performed among this group. Complicated (gangrenous or perforated) appendicitis cases consisted of 34 LAs and 26 OAs. Two LA patients required conversion to OA (one patient with a histologically normal appendix and one with gangrenous appendicitis). The negative appendectomy rate was 8% (LA, n=12; OA, n=3).

The appendectomies were performed by 24 different surgeons (6 pediatric surgeons and 18 general surgeons). Appendectomies per surgeon in this series ranged from 1 to 38 (mean, 8.2). Each surgeon reported extensive personal experience with laparoscopic surgery, and many answered a detailed questionnaire. These surgeons, who performed 79% of the LAs, had an average of 9 years of laparoscopic experience after residency or fellowship, and performed, on average, 105 laparoscopic surgeries per year.

Preoperative demographics for the patients were similar among the 2 groups **(Table 2)**. The average age of the patients was 10.4 years (range, 2 to 18).

Acute Appendicitis

Preoperative variables including temperature, white blood cell count (WBC), mean wait until surgical treatment, and proportion of patients with advanced imaging studies were similar among the acute appendicitis groups. A significant difference with respect to insurance status was found among the patients who underwent open appendectomy for acute appendicitis: 65% of the 23 acute appendicitis patients with no insurance underwent open appendectomy. However, of the 97 acute appendicitis patients with insurance (private or public), only 37% underwent OA (P=0.047).

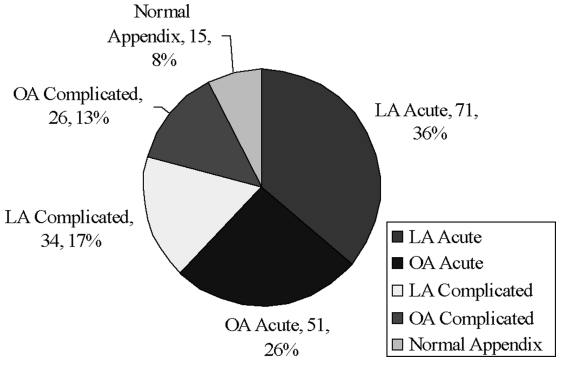

Figure 1. Study population.

Operation times among the acute appendicitis cases were similar. The mean LA time was 47 minutes (range, 25 to 94), compared with 48 minutes (range, 23 to 102) for OA. No drains were placed in acute appendicitis patients. For the 117 LA patients, 3 trocars were utilized in 116 of the patients (99%) and 4 trocars in 1 patient (1%). The mean combined skin incision length was 23 mm (0.9 inches), with a range of 13mm to 32 mm. The most commonly used trocars were a 12-mm umbilical trocar and two 5-mm trocars for a total incision length of 22 mm (0.87 inches), which was used in 78 of the 117 LA patients (67%). OAs were performed via muscle-splitting transverse right lower quadrant abdominal incisions.

Postoperative outcome measures of mean time on intravenous antibiotics, intravenous opiates, and complication rates were similar between the 2 acute appendicitis groups. LA patients experienced a faster return to full diet (LA, 17.6 hrs; OA, 28.6 hrs, P=0.001) and shorter postoperative LOS (LA, 1.06 days; OA, 1.67 days, P<0.0001) **(Figure 2)**, while accumulating greater total hospital charges (LA, $9,730; OA, $8,434, P=0.012) compared with the OA group.

Complicated Appendicitis

For complicated (gangrenous or perforated) appendicitis cases, preoperative variables and postoperative outcomes were similar among the 2 groups. Operation times were significantly longer for the LA group, with LA lasting on average 65 minutes, as opposed to only 51 minutes for their OA counterparts (P=0.028). Total hospital charges were $14,244 for LA and $13,451 for OA (P=NS). Nineteen percent of complicated OA patients had drains placed as opposed to 13% of the complicated LA cases (P=NS). While the complication rate for complicated cases of appendicitis was twice the rate of the LA group, this difference was not statistically significant **(Table 3)**.

Fourteen of the 117 LA cases (12%) had other intraabdominal or pelvic pathology identified during surgery as opposed to only 6 of the 80 (7.5%) OA cases.

DISCUSSION

Despite the recent publication of several large laparoscopic appendectomy series and meta-analysis studies in

Table 2.
Preoperative Patient Demographics*

Variable	Acute Appendicitis		Complicated Appendicitis	
	OA	LA	OA	LA
Mean age (y)	10.9	10.7	9.1	10.8
Sex (male/female)	14/37	32/39	18/9	20/13
Mean temperature (°C)	37.7	37.7	38.4	37.9
Mean white blood count ($\times 10^9$/L)	15.8	16.1	16.5	18.9
Insurance status†				
Private	27	43	16	24
Public	9	18	3	7
None	15	8	7	3
Mean wait till operating room (h)	8.1	8.2	13.3	8.8
Advanced radiographic imaging studies	57	51	57	38

*N = 180; 17 patients excluded from this table: 2 patients insurance status was not known and 15 patients with normal appendices not included.

†Statistical significance was established at $P < 0.05$.

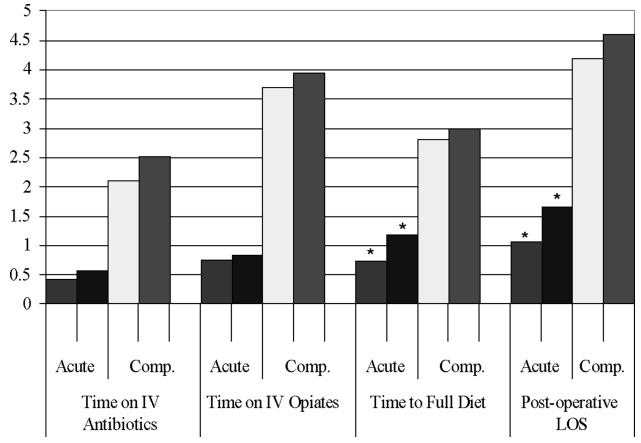

Figure 2. Outcomes. All values shown are means. *Statistical significance was established at $P<0.05$. Comp=complicated (gangrenous or perforated) appendicitis.

Table 3.
Complications

Complication	Acute Appendicitis		Complicated Appendicitis	
	OA	LA	OA	LA
Abscess	0	1	4	3
Gastroenteritis	0	1	1	0
Antibiotic allergy (rash)	0	0	1	0
Small bowel obstruction	0	0	0	1
Ascites	0	1	0	0
Atelectasis	0	0	1	0

adults demonstrating clear advantages in outcomes, laparoscopic appendectomy has yet to become fully accepted for the treatment of pediatric appendicitis.[1,2] Many studies in children comparing OA and LA consist of relatively small sample sizes. Examples include published series from Horwitz et al[5] (49 patients), Lintula et al[9] (61 patients) and Lavonius et al[10] (43 patients). The few randomized controlled trials have suffered from weak design or poor patient selection criteria, or both of these. For example, Little et al's[11] 2002 study and Lintula, et al's[9] 2001 study have been criticized for their 18% and 30% negative appendectomy rates, respectively. Another criticism of recent comparison studies is the failure to separate outcomes of acute appendicitis patients and those with complicated appendicitis despite often-dramatic differences in the morbidity of the 2 conditions.

Operation times for LA were greater than those of OA in 8 of the 18 series listed in **Table 1**, not different in 9 of the series, and not reported in one. In the current series, mean operative times were similar for acute appendicitis. However, for complicated appendicitis in this series, LA took 27% longer, on average, than OA. Since this amounts to

only 14 minutes, on average, in children with mean postoperative hospital stays over 4 days, its clinical significance may not be great.

An advantage of this study is the documented laparoscopic experience of the pediatric and general surgeons before the study period. This experience resulted in a very low laparoscopic to open conversion rate (1%), comparable operative times between the 2 groups for the simple appendicitis cases, and a low negative appendectomy rate (8%). By studying patients operated on exclusively by surgeons who had extensive experience with both the laparoscopic and the open technique, this should eliminate the confounding variable of the surgical "learning curve" often seen in previous laparoscopic appendectomy reports.

Unfortunately, the "learning curve" for proficiency in laparoscopic appendectomy has not previously been defined. However, in a recent review of 3641 articles, Dagash et al[21] evaluated the published "learning curves" for several other commonly performed laparoscopic procedures. Although somewhat controversial, proficiency for laparoscopic cholecystectomy appears to be present after approximately 30 such procedures, for laparoscopic fundoplication after roughly 28 such procedures, for laparoscopic colectomy after 40, for laparoscopic herniorrhaphy after 30 to 50, and for laparoscopic splenectomy after roughly 20. In 2 published series of pediatric laparoscopic appendectomy patients, the authors have commented on a significant improvement in operative time or risk of conversion to open appendectomy after 5 years of laparoscopic experience.[7,8] It would seem reasonable, therefore, to assume that surgeons who had performed at least 20 laparoscopic appendectomies and had been performing the operation for at least 5 years (as had each surgeon in this series) would likely be considered proficient in the operation.

In this series, laparoscopic appendectomy for the treatment of simple, acute appendicitis in children appeared to offer a quicker return to full diet and shorter postoperative length of stay. This is likely due to multiple factors. First, the laparoscopic surgeon's ability to minimize manipulation of the cecum and ileum may decrease the degree of postoperative adynamic ileus and allow one to resume a full diet earlier. Secondly, the trocar incisions appear to cause minimal trauma to the abdominal wall and probably less pain.

In this study, hospital charges for the laparoscopic appendectomy patients with acute appendicitis averaged 15%, or $1,296, more than for OA. This is presumably due to increased operating room charges and was not quite offset by the cost savings from decreased length of hospital stay for the simple acute appendicitis cases. Other authors have shown no significant difference in the charges for laparoscopic appendectomies.[11,16,22] For complicated appendicitis, mean hospital charges for the LA group were only $793 greater than charges for the OA group (P=NS). This was an unexpected finding because the difference in the acute appendicitis cases was almost $1,300. However, the smaller difference may be partially due to the fact that while 57% of the complicated OA patients underwent preoperative abdominal imaging studies [computed tomography (CT) and ultrasound (US)] only 38% of the complicated LA patients did so. CT typically increases hospital charges at our institution by over $2,000.

Laparoscopic surgery has long been felt to have the benefit over open abdominal surgeries in its superior ability to explore the abdomen and pelvis. The findings of other pathology in 12% of the LA cases versus 7.5% of OA further support this belief. The laparoscopic approach appears to be especially beneficial in female patients, in which a wider differential diagnosis for the acute abdomen must be considered. Six of the 14 cases of other pathology identified in the LA were of fallopian tube or ovarian pathology, while no OA cases observed female gonadal pathology.

Limitations of this study include the lack of randomization and its retrospective design. The finding of an increased use of open surgery in uninsured patients is of unclear significance. Furthermore, factors not evaluated in this study, and most others, were the return to normal function outside the hospital (such as ability to participate in sports and play), patient or parent satisfaction, or both, and cosmetic results associated with each method. These factors can only be studied prospectively and would require a follow-up visit or parent survey.

CONCLUSION

Laparoscopic appendectomy appears to offer significant advantages over open appendectomy for the treatment of acute appendicitis in children and offers no major disadvantages to children undergoing treatment of complicated appendicitis.

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