

# Prospective evaluation of a primary laparoscopic approach for children presenting with simple or complicated appendicitis

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Manuscript received April 15, 2006; revised manuscript August 10, 2006

Presented at the 58th Annual Meeting of the Southwestern Surgical Congress, Kauai, Hawaii, April 3–7, 2006

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## Abstract

**Background:** Previous studies have suggested laparoscopy leads to an increased risk of postoperative intra-abdominal abscess formation in complicated appendicitis. The purpose of this study is to prospectively evaluate a standardized laparoscopic approach applied by a single surgeon for all children who present with appendicitis and to determine the postoperative outcome.

**Methods:** Over a 5-year period (2001–2005), all children presenting to the author with simple or complicated appendicitis were approached laparoscopically and their preoperative workup, intraoperative findings, and postoperative outcomes recorded.

**Results:** One hundred seventy-five consecutive laparoscopic appendectomies were performed with no open conversions. Mean patient age was 9 years. Sixty-seven patients (38%) presented with complicated appendicitis. The overall complication rate was 6% (9 children developed a postoperative intra-abdominal abscess or phlegmon and 2 had umbilical wound infections).

**Conclusions:** When laparoscopic appendectomy is used as the primary technique, only 6% of patients experience infectious complications. Therefore, a laparoscopic approach to all children presenting with appendicitis does not lead to an increased complication rate. © 2006 Excerpta Medica Inc. All rights reserved.

*Keywords:* Appendicitis; Children; Laparoscopy; Perforated appendicitis; Intra-abdominal abscess; Minimally invasive surgery

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Since the first laparoscopic appendectomy was reported by Semm in 1983, the appropriate application of this technique has remained controversial [1,2]. Laparoscopic appendectomy has been well described in adult [1,3,4] as well as pediatric patients [5–7] and has been widely adopted by many practicing surgeons. However, previous studies have suggested laparoscopy may lead to an increased risk of postoperative intraabdominal abscess formation in complicated appendicitis [8,9]. Therefore, many investigators maintain that the use of a laparoscopic approach for appendicitis should be more selective, especially in the pediatric population [10,11]. The purpose of this study is to prospectively evaluate a standardized laparoscopic approach applied by a single surgeon for all children who present with

appendicitis, whether simple or complicated, and determine the postoperative outcome. The author hypothesized that a standardized laparoscopic approach in all children with appendicitis would not lead to an increased complication rate and would be technically possible in the overwhelming majority of patients.

## Materials and Methods

### Study population

The author has been on staff at The Children's Hospital and faculty at the University of Colorado Health Sciences Center, Denver, CO, over a 5-year period from 2001 to 2005. Over that time, all children ( $\leq 18$  years of age) presenting to the author with signs and symptoms of acute appendicitis underwent laparoscopic appendectomy rather than an open procedure. This minimally invasive approach was undertaken whether the patient was found to have simple or complicated appendicitis. Complicated appendicitis

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citis was defined as the presence of an abscess or phlegmon with significant free fluid on preoperative imaging, gross evidence of perforation at operation, or pathologic confirmation of appendiceal rupture. Patients with chronic abdominal pain undergoing diagnostic laparoscopy or those who had an incidental appendectomy during a different primary procedure (eg, Ladd's procedure for intestinal malrotation) were excluded. Data were collected prospectively and included age, gender, radiographic studies performed, pre- and postoperative diagnoses, intraoperative findings, procedure, operative time, surgical pathology, length of hospital stay, and any postoperative complications. All patients were evaluated by the author in at least 1 follow-up clinic visit 2 to 4 weeks postoperatively.

### *Surgical technique*

After induction of general anesthesia, patients are placed in the supine position and a Foley catheter is placed to decompress the bladder during the operation. All patients receive preoperative intravenous antibiotics. The peritoneal cavity is accessed via an infraumbilical transverse incision using a Veress needle. Pneumoperitoneum is induced with low-flow carbon dioxide up to a pressure of 10 to 12 mm Hg. A 5- or 12-mm port (depending on the anticipated need for endostapling device) is then placed, and a 5-mm 30° laparoscope is used for the procedure. Two additional 3- or 5-mm ports (depending on patient size) are placed in the left lower quadrant and in the midline suprapubic position, being sure to identify and avoid the dome of the bladder. Three and 5-mm instruments are used for the procedure. Once the appendix is localized, dissected free and grasped, the mesoappendix is taken down under tension using hook electrocautery. This begins at the tip of the appendix and extends down to the base, staying directly on the wall of the appendix and inside the appendiceal artery. Once the base is cleared, it is ligated, and the appendix is resected using either a 12-mm endostapler or 5-mm polydioxanone endoloops are deployed at the base and the appendix sharply excised with endoscissors. The appendix is then removed through the umbilical port itself, avoiding direct contact with the umbilical skin or subcutaneous tissues. If a 12-mm umbilical port is in place for the endostapler, the appendix is placed in an endocatch bag before removal.

After appendix removal, the abdomen and pelvis are thoroughly irrigated with warm sterile saline solution until clear. If an abscess cavity is present in complicated appendicitis, this is drained completely and irrigated until clear along with the rest of the abdominal and pelvic cavity. If the appendix is able to be located without too much difficulty, laparoscopic appendectomy is completed and a suction drain is left in the abscess bed and brought out through the suprapubic port site (this was done in 16 of the complicated appendicitis patients). These drains were left on bulb suction and removed postoperatively once output was less than 20 mL/d. If the abscess is mature and well formed and further dissection to reveal the appendix appears hazardous because of tightly adherent bowel or genitourinary structures, a drain is placed and the patient treated with intravenous antibiotics (triples) with plans for a laparoscopic interval appendectomy in 4 to 6 weeks (discussed further in Results section).

Muscle fascia at 5- and 12-mm port sites is closed with absorbable suture, and the skin is always closed with absorbable subcuticular suture. The urinary catheter is usually removed at the completion of the case, except in complicated appendicitis when significant third spacing of fluid is expected and the catheter is then left in place for close monitoring of urine output postoperatively. All procedures were performed with either a pediatric surgical fellow or a senior or junior surgical resident.

### *Postoperative management*

In patients with simple appendicitis, postoperative antibiotic therapy consists of 2 doses of a second-generation cephalosporin intravenously. With complicated appendicitis, the primary treatment is with intravenous piperacillin/tazobactam for 3 to 7 days in the hospital and then oral antibiotic administration at home for an additional 5 to 7 days (amoxicillin/clavulanate for those <8 years old and ciprofloxacin and metronidazole for patients  $\geq 8$  years). Patients with widespread intraabdominal contamination receive triple intravenous antibiotics while in the hospital (ampicillin, gentamicin, and metronidazole). Criteria for discharge home in patients with complicated appendicitis include being afebrile for at least 24 hours, tolerating a regular diet, ambulating with adequate pain control, and a normal white blood cell count.

### *Statistical analysis*

Data are recorded as the mean  $\pm$  standard error of the mean. Nominal data (eg, gender and complications) were compared by a Fisher exact test and continuous data (eg, age and length of stay) were compared by analysis of variance using Scheffe's F procedure. A *P* value of  $<.05$  was considered statistically significant.

### **Results**

During the 5-year study period, 175 children were diagnosed preoperatively with appendicitis and underwent laparoscopic appendectomy. There were no primary conversions to an open procedure. The entire study population had a mean age of  $9.0 \pm 0.4$  years (range from 9 months to 18 years old), and 101 (58%) were male. Preoperative radiographic studies (computed tomography [CT] scan or ultrasound) were performed on 147 (84%) of these patients, either at The Children's Hospital or at a referring institution before transfer. Mean operating room time (from incision to skin closure) was  $53.3 \pm 1.6$  minutes (range, 22-124 minutes), and mean length of hospital stay was  $3.4 \pm 0.3$  days (range, 1-23 days). Nine normal appendices were removed, resulting in a negative appendectomy rate of 5% (9/175). Of the children who had a normal appendix removed, other diagnoses were identified and often treated laparoscopically as outlined in Table 1. Interestingly, 4 of these patients had preoperative CT scans read by an attending radiologist as positive for appendicitis, and 2 others were read as equivocal. An additional teenage female patient with acute appendicitis confirmed pathologically also had the incidental finding of bilateral ovarian teratomas. Eleven patients experienced postoperative complications including intra-abdominal abscess/phlegmon formation and umbilical wound

Table 1  
Alternative diagnoses in children with a normal appendix

Pathology	Number	Laparoscopic management
Ovarian cyst	1	Drainage and partial excision
Meckel's diverticulitis	1	Diverticulectomy
Omental cyst with torsion	1	Partial omentectomy
RLQ adhesions	1	Adhesiolysis
Pelvic inflammatory disease	1	Culture of pelvic fluid
None	4	None

RLQ = right lower quadrant.

infection for a total complication rate of 6% (11/175). There was no operative mortality, but 1 death did occur in a delayed fashion because of complications related to acute myelogenous leukemia.

Patients are divided into simple and complicated appendicitis in Table 2. Sixty-seven (38%) presented with complicated appendicitis. Eight of the complicated appendicitis patients had a well-formed appendiceal abscess identified on preoperative CT scan. They underwent either interventional radiology guided (6), laparoscopic (1), or transrectal drainage (1) of the abscess with continued antibiotic treatment. No patient required repeat drainage. Three additional patients presented with a localized but large and complex right lower quadrant phlegmon and were treated with broad-spectrum intravenous antibiotics (triples). The mean hospital stay for these patients initially treated nonoperatively was  $8 \pm 1.3$  days. With resolution of the abscess/phlegmon on repeat CT scan and symptomatic improvement, these patients were discharged home and returned for an interval appendectomy in 4 to 6 weeks (all completed laparoscopically). One patient returned in 3 weeks with a recurrent phlegmon and underwent interval laparoscopic appendectomy at that time instead of waiting.

As depicted in Table 3, there was no difference in gender between the simple and complicated appendicitis groups. Children with complicated appendicitis were younger than those presenting with simple appendicitis as might be expected. Pediatric patients with complicated appendicitis had significantly longer operative times and longer hospital stays. In addition, the postoperative complication rate was also significantly higher in those who presented with evidence of perforation (13% vs 2%). The specific complications and how they were managed are outlined in Table 3. The most common postoperative complication was the development of an intra-abdominal abscess (6 of 11 patients,

Table 2  
Children with simple versus complicated appendicitis

	Simple	Complicated (%)
Number	108 (62)	67 (38)
Male	62 (57)	39 (58)
Age (y)	$10.5 \pm .5$	$7.3 \pm .6^*$
OR time (min)	$45.3 \pm 1.3$	$65.9 \pm 3.0^*$
LOS (days)	$1.4 \pm .1$	$6.2 \pm .5^*$
Complications	2 (2)	9 (13)*

LOS = length of hospital stay; OR = operating room.

\*  $P < .05$  compared with the simple appendicitis group.

Table 3  
Postoperative complications after laparoscopic appendectomy

Complication and treatment	Simple (n = 108) (%)	Complicated (n = 67) (%)
Intraabdominal abscess (IR drainage)	0	5 (8)*
RLQ phlegmon (IV antibiotics)	1 (1)	2 (3)
Multiple intra-abdominal abscesses (laparotomy)	0	1 (1)
Umbilical wound infection	1 (1)	1 (1)
Total	2 (2)	9 (13)*

IR = interventional radiology; RLQ = right lower quadrant.

\*  $P < .05$  compared with the simple appendicitis group.

all in children presenting with complicated appendicitis). The majority were able to be drained by interventional radiology and resolved with further antibiotic therapy. One patient who presented with massive intra-abdominal contamination from perforated appendicitis subsequently required a limited laparotomy for drainage of multiple abscesses after laparoscopic appendectomy. This patient also accounted for the longest hospital stay of 23 days. The 2 umbilical wound infections drained spontaneously and resolved with further wound care and oral antibiotic therapy. One patient with simple appendicitis and 2 with complicated appendicitis required readmission for intravenous antibiotic treatment of a right lower quadrant phlegmon that resolved without any further surgical or radiologic intervention.

### Comments

Minimally invasive surgical techniques have been widely adopted in adult surgery over the last 2 decades. Pediatric surgeons were initial leaders in the field largely because of the pioneering work of Dr Stephen Gans in "peritoneoscopy" as early as the 1970s [12]. However, broader application of these minimally invasive techniques in children has required significant technological advances to decrease the size of endoscopes as well as further downsize endoscopic instrumentation. As 3- and 5-mm laparoscopes with excellent visualization and small versatile endoscopic instruments have become available, surgeons have recognized the potential benefits of decreased operative trauma resulting in quicker recovery, shorter hospital stays, and improved cosmesis. It is now estimated that up to 82% of pediatric surgeons in the United States perform laparoscopic surgery to some extent [13].

Acute appendicitis continues to be the most common surgical emergency in the pediatric population. Open appendectomy has been the gold standard in terms of operative approach and has very well-established and excellent results. As a result, laparoscopy has only gradually been introduced as a surgical technique to treat appendicitis. In 1993, a review of the "current" status of laparoscopic appendectomy in children reported only 28 such procedures performed over an 18-month period [14]. At that time, it was noted that laparoscopy resulted in longer operative times and was more expensive. By the time the next "current" status was reported in 1998, experience with a much larger cohort of 245 children was described [15]. The au-

thors reported at that time that operative times were not prolonged; costs were similar with reusable equipment; and pediatric patients had a quicker recovery, less pain, and fewer wound infections. Over 5 years, the assessment of laparoscopic appendectomy had changed significantly.

The earlier studies comparing open versus laparoscopic appendectomy were reported in adult patients. In 1994, Frazee et al [4] randomized 37 patients to open appendectomy and 38 to laparoscopic appendectomy. They reported that the operative time was longer in the laparoscopic group (87 vs 65 minutes), but patients required less parenteral and oral analgesics and returned to full activity significantly quicker (14 vs 25 days). Chung and colleagues [16] performed a meta-analysis of 17 randomized trials and confirmed that the laparoscopic approach to acute appendicitis took 31% longer. Although hospital stay was similar between the 2 groups, laparoscopic patients had a 35% faster recovery and experienced reduced postoperative pain. Furthermore, they found a remarkable 60% reduction in wound infection rates. They concluded that laparoscopic appendectomy offers significant improvement in postoperative outcomes at the cost of a longer operation.

One of the first studies in children was reported in 1992 [17]. In this relatively small study, the investigators compared 50 open appendectomies with 14 done laparoscopically. They reported a longer operating time and higher cost but also documented a significant decrease in inpatient days (2.9 vs 5.4 days) and quicker return to full activity (1.6 vs 4 weeks) in the laparoscopic appendectomy pediatric patients. A much larger retrospective report came out of France in 1994 [5]. They reported a multicenter experience with nearly 1,400 laparoscopic appendectomies in children. There was no mortality, but 2 visceral punctures and 2 omental eviscerations were described. The overall complication rate was only 1.5% with major complications reported as 0.6% (3 bowel obstructions, 4 postoperative abscesses, and 2 wound infections). In addition, nonappendiceal lesions were identified in 10% of pediatric patients. Hospital stay was 2 days in simple appendicitis and 4.5 days with complicated appendicitis with peritonitis.

Because more surgeons used laparoscopy in the diagnosis and treatment of simple as well as perforated appendicitis in children, concerns about higher complication rates were raised. Horwitz et al [10] reported a retrospective review in 1997 comparing children with perforated or gangrenous appendicitis undergoing an open versus laparoscopic approach. They reported a 4-fold increase in overall complications in the laparoscopic group and specifically a 5-fold increase in postoperative intra-abdominal abscess formation (50% in the laparoscopic cohort). These concerning results were followed by a report from Krisher and colleagues [11] in 2001. They reviewed 170 children with complicated appendicitis and reported an increased rate of postoperative intraabdominal abscess formation of 24% in the laparoscopic group versus 4% after open appendectomy. This yielded a relative risk ratio of 5.6. However, there have been conflicting data reported by others. Four pediatric surgeons in San Diego reported a large experience with 1,128 appendectomies, 955 of which were removed laparoscopically [6]. Thirty-five percent of these were perforated at time of presentation, and they found no difference be-

tween the 2 groups in the rate of postoperative intra-abdominal abscess formation (6%). Another report in 2003 reviewed 324 children undergoing appendectomy, 204 of which were done laparoscopically [18]. They also found that the incidence of postoperative abscess formation in the complicated appendicitis group was not significantly different (15% laparoscopic vs 10% open). Others have reported similar results [19,20]. The 1 randomized trial of laparoscopic versus open appendectomy in children excluded patients with evidence of peritonitis [21].

The author's training in pediatric surgery fellowship included a broad exposure to both laparoscopic as well as open techniques for appendectomy. It was anecdotally noted that children operated on laparoscopically did very well postoperatively and did not seem to have an increased complication rate. In addition, the need to convert to an open procedure was rarely necessary. At the completion of training and beginning as faculty at The Children's Hospital, a conscious decision was made to approach every child with appendicitis laparoscopically, whether simple or complicated, and to collect data prospectively in order to constantly evaluate my results. The data from this study show that a standard laparoscopic approach to all children with appendicitis is not only feasible but is entirely safe and effective. Even in a training institution, laparoscopic appendectomy does not necessarily take longer to perform because the mean operative time was 53 minutes. This is equal to or less than many reports concerning open appendectomy. One reason for these expedient laparoscopic procedures is our well-prepared operating room staff. They are able to set up laparoscopic cases appropriately, and scrub technicians are well versed in the procedures because we perform them regularly, day and night. I also submit that appendectomy is the optimal training experience for junior residents just beginning to learn laparoscopic techniques, as well as more senior residents and fellows to perfect their minimally invasive skills.

Furthermore, we have not seen the higher rate of complications, specifically the high rate of intra-abdominal abscess formation reported by others. The author's overall complication rate is a relatively low 6%. Even in the subgroup of children presenting with complicated appendicitis, postoperative intra-abdominal abscess formation was documented in only 9%. This is much lower than the 20% to 40% rate reported in some studies previously mentioned [10,11]. This lower rate may be secondary to the thorough abdominal and pelvic irrigation that can be performed laparoscopically or that drains can be well placed under laparoscopic guidance when an abscess cavity is present. In addition, more children are identified preoperatively with a localized perforation and possible abscess and are being treated with intravenous antibiotics  $\pm$  abscess drainage followed by delayed laparoscopic interval appendectomy. The key to patient selection for nonoperative management is that the inflammatory process secondary to appendiceal perforation is focal, either a localized well-formed abscess or limited phlegmon without evidence of widespread intraabdominal contamination. In addition, patients with evidence of sepsis should also be excluded and instead proceed to the operating room for exploration. With appropriate patient

selection, this method is very successful and avoids more widespread contamination of the abdominal cavity.

In a review of the management of appendicitis at 30 pediatric hospitals [22], the use of laparoscopic appendectomy ranged from 0% to 95%, with a mean of 31%. A recent survey of pediatric surgeons in North America [23] reports that 39% never or rarely use laparoscopy for acute appendicitis and only 11% always use laparoscopic techniques. These data reveal a significant variability in practice patterns and management philosophy. Conclusions from this single-institution, single-surgeon experience are somewhat limited. Laparoscopic appendectomy can certainly be performed safely in all children who present with either simple or complicated appendicitis. The procedure is efficacious, does not take longer in the operating room, and the complication rate is low. Other intra-abdominal pathology can be diagnosed as well as treated, usually without converting to an open operation. Laparoscopic appendectomy can also serve as an excellent base for surgical resident training, and patients definitely appreciate the improved cosmetic results.

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## Discussion

**Atul Madan, M.D.** (Memphis, TN): This is a prospective single-institution, single-surgeon experience of 175 children over a 5-year period who underwent laparoscopic appendectomies. The description of the technique and presentation of results are very good, with an overall infectious complication rate of 6% or 13% for those specific patients presenting with complicated appendicitis. In this surgeon's hands, laparoscopic appendectomy yields excellent results. A better study would have been to randomize patients to laparoscopic versus open appendectomy. I do understand the reluctance of performing that study. The author's operating time was 45 minutes in simple appendicitis and 66 minutes in complicated appendicitis. This is reasonable, especially in light of this being done in a training environment. Abscess formation occurred only in 9%. I do have some questions. Do you think these results are generalizable to most other pediatric surgeons at most institutions? Do you think these data would be similar in adults if performed by a well-trained surgeon? Last question, what do the other surgeons at your institution do when encountering a child with appendicitis? For those who perform open appendectomy, is there any hope in training and/or convincing them to perform laparoscopy?

**Steve Smith, M.D.** (Wichita, KS): During your presentation, you mentioned the avoidance of stapling devices as a cost-saving maneuver. Do you have any cost analysis data for the laparoscopic approach in your hands versus an open approach in others at your institution? Secondly, have you noticed a faster return to normal activities in the pediatric population with a laparoscopic approach versus an open approach?

**David Partrick, M.D.** (Denver, CO): One reason why it would have been difficult to do a comparison between laparoscopic and open is that the practice at our institution has been very selective. Some of the attendings will decide, according to the CT scan results, if they are going to do the procedure laparoscopically or open. If it looks complicated, they will just plan to do it open from the start. So it is a very select population in terms of who ends up getting open

appendectomies. There are also some faculty who still do most of them open but will use laparoscopy when the diagnosis might be unclear or maybe in the adolescent female. I have presented some of these data at our weekly surgical conference, and as a result more of the faculty members are leaning toward doing laparoscopy. A lot of this change depends on becoming comfortable with the technique. From my standpoint, that goes back to our resident training. All of these procedures are done with residents and that alludes to your first question whether this experience can be generalized. These are excellent learning procedures for the residents. Rather than learning laparoscopic techniques with a fundoplication or something that might be a little more complicated, I think techniques learned performing appendectomy are very generalizable. In terms of comparison with adults, watching that last video presentation about laparoscopic surgery on adults with sigmoid diverticulitis, I was reminded why I went into pediatric surgery. All the internal fat can make things more difficult. But, obesity is becoming more and more prominent in children also and I think that significantly increases morbidity from the procedure. But, I would submit that with laparoscopy, the

complications such as wound infections in obese patients are going to be much lower.

Dr Smith, the cost analysis is a good question. A stapling device costs at least \$250 as soon as you open it, whereas in the endoloops we use are less than \$50. I have not done any formal cost analysis, but I do know that operating times are not significantly longer. A lot of the previous studies that did cost analysis were done within the learning phase of laparoscopic surgery and the cases took much longer. The other thing that saves a lot of money in these cases is using reusable ports and instruments. All of our instruments are reusable, and our 3-mm ports are all reusable. In terms of a faster return to regular activity, that is more difficult to quantitate in kids. They are so motivated to be up and out of the hospital, it does not seem to matter how the appendix is removed. I think they all return to regular activity pretty quickly. There are studies that show significant improvement in terms of return to activity in laparoscopic patients, but I think the more significant factor is the decrease in wound infections rates. And the patients, as well as their families, are also appreciative of the cosmetic benefit from approaching these cases laparoscopically.