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Operative management of appendicitis

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ABSTRACT

Appendectomy has been the standard of care for appendicitis since the late 1800s, and remains one of the most common operations performed in children. The advent of data-driven medicine has led to questions about every aspect of the operation—whether appendectomy is even necessary, when it should be performed (timing), how the procedure is done (laparoscopic variants versus open and irrigation versus no irrigation), length of hospital stay, and antibiotic duration. The goal of this analysis is to review the current status of, and available data regarding, the surgical management of appendicitis in children.

The operative management of appendicitis varies with the extent of disease at presentation. The three general categories of disease are those with appendicitis with no evidence of perforation, those with perforated appendicitis, and those who present with a well-defined abscess. This article will review the definition and application of this classification schema and the available data on the various operative approaches and technical factors associated with the surgical procedures in use currently.

Acute appendicitis

Acute non-perforated appendicitis is definitively cured with prompt appendectomy, and this is the rationale for early operation as the traditional standard of care. We now understand that acute appendicitis can be treated effectively to the point of disease resolution and hospital discharge with antibiotics alone.[1–3] This concept is discussed at length in another section of this edition. However, emerging data demonstrating the ability to treat appendicitis with antibiotics lends insight to a long debated topic, the timing of appendectomy relative to presentation. If antibiotics alone can treat the disease, it would be rational to assume that once antibiotics are started, the operation is not emergent or perhaps even necessary, in the immediate setting. The primary concern around which any argument regarding the timing of appendectomy is centered, is the possibility that patients with non-perforated appendicitis will progress to perforation if there is a delay in performing appendectomy. A retrospective study suggested that a longer in-hospital wait for operation was associated with a higher-perforation rate in children. However, the patients appear to have been highly selected, since no one who underwent appendectomy within 9 h had a perforation,[4] implying that no one in the early operative group had a perforation at admission. Given the known data regarding the percentage of children with perforation or complicated disease, this is quite atypical and suggests selection bias. This study also focused only on time from presentation to operation. A more recent study investigating time to appendectomy relative to onset of symptoms found no association between a longer time to appendectomy and worse outcomes.[5] Both of these studies involved relatively small cohorts. A recent multicenter study including over 1300 patients demonstrated that delay in appendectomy did not impact the incidence of surgical site infections.[6] The only variables correlating with surgical site infections were the duration of symptoms, shock or sepsis at presentation, and the presence of complicated appendicitis. Since the most robust data available suggest timing of appendectomy does not impact adverse event rates, appendectomy in the middle of the night is no longer justified. National health care trends toward maximizing system efficiency and delivery of care, combined with data suggesting overnight appendectomy places undue stress on the surgeon, surgical team, family, and hospital staff[7–9] argue for approaching appendectomy as an elective procedure once antibiotic therapy has been initiated. This information may be useful during the initial consultation, to ease patient and family anxiety.

Perforated appendicitis

The best management strategy for perforated appendicitis is still a topic of debate. The three options consist of antibiotics only, antibiotics followed by interval appendectomy, and appendectomy at presentation.

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The rationale for treating initially with antibiotics is to avoid a difficult operation in the setting of peritonitis. Once the infection is controlled with antibiotics and operative difficulty is decreased, then the decision is whether to even perform the appendectomy or not. Foregoing the appendectomy assumes a low risk of recurrent appendicitis; short-term data suggest the risk is approximately 8–14%.[10,11] It is currently impossible to estimate the lifetime risk of leaving the offending organ in place. There are no longitudinal population-based studies of these children as they mature through adulthood and old age; therefore, recurrence curves are unknown quantity. However, assuming the current series are accurate in estimating the short-term risk of recurrent appendicitis at 1–3% per year, and that the rate remains stable, appendectomy may be indicated in a child with 60–80 years of life expectancy. We found only 16% of patients had luminal obliteration at the time of interval appendectomy, implying the remaining appendices would remain at risk for recurrent appendicitis.

Additionally, some authors have noted a high rate of pathologic findings in interval appendectomy specimens.[12–14] Although rare in children, missed appendiceal neoplasms are a potential undesirable side effect of the non-operative approach. A survey of the American Pediatric Surgical Association (APSA) in 2005 found that 86% of the responders perform interval appendectomy routinely after non-operative management of perforated appendicitis.[15]

Initial management with antibiotics followed by elective appendectomy depends on the patient responding to medical management and becoming asymptomatic. Several groups have attempted to evaluate which patients are more likely to fail and require an early appendectomy prior to the scheduled interval operation. A study found a high-failure rate in patients with more than 15% band forms in the differential white cell count on presentation.[16] The presence of an appendicolith on imaging has also been associated with failure of medical management.[17] Others have found that evidence of disease or contamination beyond the right lower quadrant on imaging was a predictor of failure.[18]

The management pathway of initial antibiotic therapy followed by interval appendectomy includes a *de facto* assumption that the clinician can distinguish perforated from non-perforated appendicitis based on the preoperative presentation (clinical, laboratory, and radiographic studies). A blinded review of CT scans at our institution found that radiologists and surgeons (of all levels of experience) were unable to diagnose perforation with greater than 80% accuracy.[19] Treating a child with non-perforated appendicitis with a protracted course of antibiotics and interval appendectomy is gross overtreatment. These patients do not require post-operative antibiotics after appendectomy and currently are usually discharged from the hospital on the day of operation.[20]

While the goal of “antibiotic therapy first” is to avoid a difficult and potentially dangerous operation, this has been documented to be an operation that most experienced surgeons can perform safely, and with a minimally invasive approach. Laparoscopic appendectomy has been shown to be reliably feasible and safe in both children and adults who present with a phlegmonous right lower quadrant mass.[21,22]

Several studies have compared early versus delayed appendectomy for perforated appendicitis, culminating in a meta-analysis published in 2010. This report reviewed 17 studies, 16 of which were retrospective and non-randomized; the other was prospective but non-randomized.[23] This review compared 847 patients who underwent delayed appendectomy and 725 who underwent early appendectomy. The delayed operation was associated with significantly less overall complications, wound infections, abdominal/pelvic abscesses, ileus/bowel obstructions, and reoperations. No significant difference was found in the duration of first hospitalization, the overall duration of hospital stay, and the duration of intravenous antibiotics. Overall complications remained significantly less in the conservative treatment group during sensitivity analysis of studies including only pediatric patients. Due to the poor-quality data, the authors suggested that high-quality studies were necessary for a definitive conclusion.

Higher-quality data now exists with the completion of a prospective, randomized trial comparing appendectomy on presentation to initial antibiotic therapy and appendectomy 6–8 weeks later.[24] Children with a presumed preoperative diagnosis of perforated appendicitis were included. They randomized 131 children with or without abscess; 64 children in the initial appendectomy group and 67 in the initial antibiotic followed by interval appendectomy group. The length of hospitalization was 2 days longer with initial antibiotics followed by interval appendectomy ($P = 0.03$). The overall adverse event rate substantially favored early appendectomy with a relative risk of 1.86 associated with initial antibiotic therapy and delayed appendectomy (95% CI: 1.21–2.87, $P = 0.003$). Importantly, children who had delayed appendectomy had higher costs and were more likely to receive a central line. The results of this trial firmly demonstrate patient benefits from early laparoscopic appendectomy in children with a preoperative diagnosis of perforated appendicitis.

Role of irrigation

An abundance of data from several decades failed to demonstrate a clinical role for irrigation in the face of peritoneal contamination.[25] Despite this lack of compelling data in all the previous studies investigating the role of irrigation, in a survey of North American pediatric surgeons published in 2004 only 7% of the respondents reported using no irrigation.[26] Two retrospective studies comparing irrigation to no irrigation during appendectomy (mostly laparoscopic) both demonstrated an increase in abscesses resulting from the use of irrigation, leading both to recommend no irrigation.[27,28]

We completed a prospective, randomized trial comparing normal saline irrigation to suction alone during laparoscopic appendectomy for perforated appendicitis in children.[29] Perforation was defined as a hole in the appendix or a fecalith in the abdomen. We had previously shown that using these criteria as the definition of perforation separated those with post-operative risk of abscess of approximately 20% (perforated) to children with an abscess risk under 1% (non-perforated).[30]

In the irrigation arm, a 1-L bag of sterile normal saline was attached to the irrigation device. A minimum of 500 mL of saline was required, with no maximum volume limit. There were 220 patients randomized. At presentation, there were no differences between the two groups in age, weight, body mass index percentile, gender distribution, duration of symptoms, presenting leukocyte count, or temperature.

The primary outcome variable was the development of an abdominal abscess, and there was no difference between groups −19.1% with suction only and 18.3% with irrigation ($P = 1.0$) developed an abscess. There was no difference in time to starting clear liquids, advancement to a regular diet, or discharge. Hospital charges were the same. There was also no difference in mean maximum daily temperatures. Additionally, there was no difference in any aspect of their management, hospital course, or outcomes. The study demonstrated miniscule effect sizes in either direction, suggesting that irrigation is unlikely to have an impact on clinical course during laparoscopic appendectomy.

Abscess on presentation

Patients presenting with a well-defined abscess on imaging studies are another focus of controversy. An option is initial