



Surgical Techniques in Pediatric Appendectomy

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Introduction

Currently, there are four common techniques used for appendectomy: open, laparoscopic, single-incision laparoscopic surgery (SILS), and transumbilical laparoscopic-assisted appendectomy (TULAA). For the sake of completeness, we will also include natural orifice transluminal endoscopic surgery (NOTES), although this technique has not been used in pediatric patients. The operations will be described in detail along with advantages and disadvantages for each. Differences in cost, operative time, hospital recovery time, cosmetic appearance, and outcomes will be taken into account, as all of these aspects are commonly used to determine which technique is most effective in a given patient population.

Discussion

Open Technique

The first appendectomy was reported in 1735 by Claudius Amyand, who operated on an 11-year-old boy when the child perforated his appendix by swallowing a pin [1]. A century later, Charles McBurney, an American surgeon, popularized his classic

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McBurney's incision, which allowed access to the right iliac fossa through a muscle-splitting and muscle-sparing technique to remove the appendix [1]. In this open approach, an incision is made in the right lower quadrant, superior to the inguinal ligament, parallel to the fibers of the external oblique muscle, allowing the muscle to be spared and thus speeding up the healing process. The cecum is visualized and the appendix is located, secured, and amputated at the base [2]. Other incisions may be used for an open appendectomy, such as the Rocky-Davis, a transverse incision, or a conservative midline incision, but these incisions cut through muscle and are therefore associated with increased pain and longer recuperation.

Open appendectomy may be performed quickly and is not very resource intensive, as it requires little other than retractors and basic suture material. Worldwide, the technique is practiced by a variety of surgical and nonsurgical providers. The operation can be done under general, regional, or even local anesthesia if necessary. Based on a large meta-analysis study, the average operating time for an open appendectomy is typically 11.5 minutes shorter than laparoscopic surgery, although this is surgeon-dependent [3]. Disadvantages include lack of clear visualization of peritoneal areas outside of the right iliac fossa and a visible scar. For example, in the case of misdiagnosis of appendicitis, examination of the ovaries in a female patient through the right lower quadrant incision is nearly impossible. In the United States, open appendectomy in the pediatric population has been supplanted by any one of a number of laparoscopic approaches as these offer decreased pain, less scarring, and, a potentially, faster recovery [4].

Laparoscopic Technique

The first laparoscopic appendectomy was reported in 1982, and this approach has become the gold standard for acute appendicitis management due to decreased post-operative pain, shorter hospital stay, and better cosmesis [1, 4]. One port is placed in the umbilicus, which is used to explore the peritoneal cavity and confirm the diagnosis of acute appendicitis [2, 5]. The ease of confirming the diagnosis is a major advantage of laparoscopic surgery over an open technique. Two additional ports, typically placed in the left lower quadrant and suprapubic areas, allow placement of working instruments. The mesoappendix is secured by staples or electrocautery, and a linear stapling device or endoloop is used to secure the base of the appendix. The appendix is then removed, often after placing it into a plastic bag endoscopically [2]. Endoloop closures appear to have outcomes comparable to those of a stapling device *vis-à-vis* operative time and safety, but are markedly cheaper [6]. Some surgeons prefer the stapler due to its ease of application and in cases where the base of the appendix is thickened or friable [2].

Innumerable studies have attempted to compare open to laparoscopic surgery in terms of operative times and costs, incidence of wound and organ space infection, pain control, and hospital stay. Meta-analyses comparing the two techniques generally suggest that laparoscopic surgery is more expensive but faster than open surgery, especially with increased practice, and results in shorter hospital lengths of stay and reduced incidences of superficial wound infections [3, 7]. Most studies also suggest that there is a slightly higher rate of intra-abdominal infections following

laparoscopic surgery for perforated appendicitis in comparison to open surgery, but these associations are less uniform [8].

Large single-center observational studies and national database studies have suggested that the laparoscopic approach for both simple and perforated appendicitis is more expensive than open but otherwise has comparable or better outcomes in terms of the above measures and leads to less postoperative pain and earlier discharge [7, 9]. No randomized control study, however, has been carried out to help prove causality, and none is likely to occur as laparoscopy has become the preferred approach among pediatric surgeons in the United States. Even in the past 5 years, techniques and approaches continue to be refined in an effort to decrease cost and shorten hospital length of stay [10, 11].

Single-Incision Laparoscopic Surgery (SILS)

Recently, single-incision laparoscopic surgery (SILS) has been introduced to the pediatric population and has shown to be equal to the conventional three-trocar laparoscopic technique [4, 5]. A 2 or 3 cm port is placed into the umbilicus, and all the tools are used through this single port. This technique requires advanced laparoscopic skills as multiple tools placed through one port can lead to instrument clashing inside and outside the abdomen. Visualization and tissue manipulation are more difficult within one port, and the operation can be more time-consuming than conventional laparoscopic surgery, particularly early in the learning curve [4, 12]. Furthermore, placement of a second port is sometimes required to allow for easier dissection and triangulation. Maintaining cosmetic advantages and decreasing pain over the three-trocar approaches takes learning as well [13]. However, with practice, these disadvantages can significantly improve over time [13, 14].

With the advancement to SILS, surgeons have been concerned about the outcomes and costs that come along with this procedure compared to traditional laparoscopic procedures. In comparing the two techniques, Wieck et al. found that in non-perforated appendicitis, SILS had significant shorter operative times, decreased costs, and shorter hospital stays. Even more so, there was no difference in the rate of wound infection or abscess formation regardless of appendicitis severity [15, 16]. In addition, postoperative analgesic requirements were equivalent, but the SILS technique was felt to have a better cosmetic outcome [15, 17].

Other studies that have shown SILS take longer time in the OR by just a few minutes, which leads to greater charges. However, they still have similar postoperative morbidity and wound infection rates [16, 18]. At this time, there is no randomized, prospective study that has compared the outcomes of SILS and laparoscopic surgery.

Transumbilical Laparoscopic-Assisted Appendectomy (TULAA)

TULAA is a further advancement in the various techniques to surgically manage acute appendicitis, first successfully completed by Pelosi in 1992 [19]. This technique combines the methods of open and single-port laparoscopic surgeries as a single port is placed in the umbilicus to explore the peritoneal cavity and visualize

the appendix. One can use a specialized port originally developed by gynecologists that has an offset camera lens or a conventional 12 mm port that allows placement of a grasping instrument alongside the camera lens (Fig. 11.1). The appendiceal tip is grasped and brought into the wound, allowing extracorporeal division of the mesoappendix and ligation of the appendiceal base (Fig. 11.2) [19, 20].

While the method may seem more complicated than the other techniques discussed thus far, it has been found to have many advantages. Primarily, it has been found to have shorter operative times compared to laparoscopic appendectomies, 33 minutes compared to 39 minutes in one study [20]. Operative costs for TULAA are markedly less compared to laparoscopic surgeries, in part due to the shorter operative times as well as the decreased reliance on disposable items. For example, TULAA uses an absorbable suture rather than staples or endoloops for appendiceal base control and does not require an endocatch bag; these savings can approach \$1000 per case [19, 21, 22].

Even when removing the appendix extracorporeally, there has been no increase in the rate of complications and wound infections [18, 23] (Fig. 11.3). Similarly, the cosmetic results have been found to be better than the other techniques [23, 24]. Some studies have found TULAA to be a practical alternative to conventional laparoscopic or open appendectomy [24, 25].

Fig. 11.1 Instruments placed side by side in single-port transumbilical operation



Fig. 11.2 Appendix grasped intracorporeally

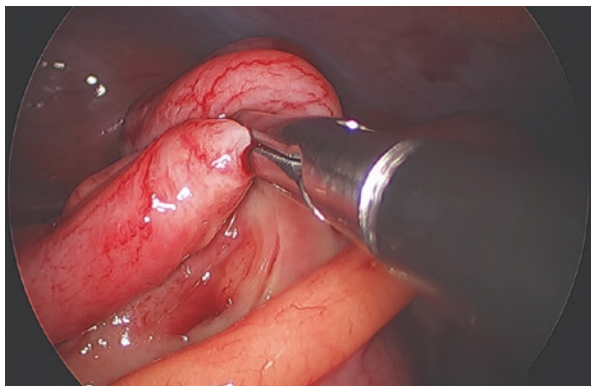


Fig. 11.3 Extracorporeal ligation of appendiceal base



However, there are some disadvantages to TULAA. Primarily, there is a steep learning curve. Using a single port can be difficult for new users as there is increased possibility of “tool clashing” [18]. Second, while using TULAA, there are situations where it is not safe to continue with one port, in which cases a second port needed

to be added, therefore, adding a second scar for the patient. Visnjic et al. found that a second port was required in 3–7% of cases, typically for complicated appendicitis [20]. With practice and time, these disadvantages can also improve.

Natural Orifice Transluminal Endoscopic Surgery (NOTES)

While SILS and TULAA are considered essentially “scarless” as there is only a transumbilical incision that is hidden within the umbilicus, surgeons continue to search for a way to remove the appendix without any skin incision. Transgastric and transvaginal appendectomies have been described in adults, although the operation often requires placement of a small umbilical assist trocar [26]. Given the ease and overall low complication rate of transumbilical surgery, as well as the slow adoption of NOTES appendectomy in adult surgery, there has been very little interest generated in pediatric NOTES appendectomy to date [27]. As instrument miniaturization evolves, NOTES techniques may someday be popularized, at least in older pediatric patients.

NOTES requires specialized tools, which may also play into part the slow adoption of this technique in both adult and pediatric populations. There is an adaptation to NOTES that has been developed to make a single incision while using the endoscope, known as single-incision pediatric endoscopic surgery (SIPES) [28]. This technique still offers essentially a scarless surgery and offers a more broad application. However, there are still some disadvantages with SIPES as exposure can be challenging and instruments clash within the single site. Table 11.1 summarizes the advantages and disadvantages of the various approaches.

Table 11.1 Comparison of appendectomy techniques

Techniques	Advantages	Disadvantages
Open	Full exposure, rule out gynecological pathology, shorter operative time, conventional and more easily available tools	Typically more postoperative pain, larger scar, longer hospital stay
Laparoscopic	Decreased pain, improved cosmesis due to smaller incisions, shorter hospital stay, conventional tools, perhaps lower risk of intra-abdominal adhesions	Greater number of scars, increased costs, longer operative time
SILS	Improved cosmesis (essentially scarless) as port is through umbilicus, shorter operative time, quicker return to physical activity, conventional tools	Advanced skills needed, can hit tools unknowingly, expensive
TULAA	Safe, effective, basically scarless, combines open and laparoscopic advantages, shorter operative time, low complications rate, excellent cosmetic results	Learning curve
NOTES	Scarless, quicker return of bowel function, decreased post-op pain	Not yet developed for use in children, expensive, difficult to maneuver, sometimes needs a port in umbilicus – adding a scar

Conclusion

Laparoscopic appendectomy has generally replaced open appendectomy in the pediatric population, although the latter is still used in rural parts of the country where adult surgeons may provide a majority of pediatric surgical care. Conventional, three-port laparoscopic surgery and its subsequent single site surgery iterations appear to be quicker and associated with fewer complications when compared to open surgery, at an increased operative cost.

Clinical Pearls

- Laparoscopic appendectomy has become the preferred method for treating pediatric appendicitis as it has shorter operative time, shorter hospital stays, decreased postoperative pain, and decreased incidence of superficial wound infections.
- TULAA allows for combining open and laparoscopic techniques, which has led to no increase in wound infections and complications, shorter operative times, and decreased operative costs compared to laparoscopic surgery.
- NOTES allows for a scarless surgery but requires highly specialized tools that will need to be developed specifically for the pediatric population.

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