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Is appendoscope a new option for the treatment of acute appendicitis?

Abstract

Acute appendicitis is a common surgical emergency. It is commonly caused by obstruction of the appendiceal lumen due to fecaliths, tumors, or lymphoid hyperplasia. For over a century, appendectomy has been the primary treatment for acute appendicitis. Abraham Groves performed the first open appendectomy in 1883. In 1983, Kurt Semm completed the first laparoscopic appendectomy, heralding a new era in appendectomy. However, appendectomy is associated with certain complications and a rate of negative appendectomies. Studies have suggested controversy over the impact of appendectomy on the development of inflammatory bowel disease and Parkinson's disease, but an increasing number of studies indicate a possible positive correlation between appendectomy and colorectal cancer, gallstones, and cardiovascular disease. With the recognition that the appendix is not a vestigial organ and the advancement of endoscopic technology, Liu proposed the endoscopic retrograde appendicitis therapy. It is an effective minimally invasive alternative for treating uncomplicated acute appendicitis. Our team has developed an appendoscope with a disposable digital imaging system operated through the biopsy channel of a colonoscope and successfully applied it in the treatment of appendicitis. This article provides an overview of the progress in endoscopic treatment for acute appendicitis and offers a new perspective on the future direction of appendiceal disease treatment.

Key Words: Acute appendicitis; Endoscopic technology; Endoscopic retrograde appendicitis therapy; Appendoscope; Appendiceal disease treatment

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Core Tip: In this article, our team has developed an appendoscope with a disposable digital imaging system operated through the biopsy channel of a colonoscope and successfully applied it in the treatment of appendicitis. It provides an overview of the progress in endoscopic treatment for acute appendicitis and offers a new perspective on the future direction of appendiceal disease treatment.

INTRODUCTION

Acute appendicitis is a common surgical emergency, most frequently occurring in the 10-20 age group, with a male-to-female ratio of 1.4:1.0[1]. It is commonly caused by obstruction of the appendiceal lumen due to fecaliths, tumors, or lymphoid hyperplasia[2]. The diagnosis of acute appendicitis still lacks a gold standard and requires a combination of clinical presentation (Alvarado score)[3] and imaging modalities such as ultrasound or computed tomography (CT)/magnetic resonance imaging (MRI) suggestive of appendicitis[4,5]. Liu[6] defines acute uncomplicated appendicitis as an appendiceal diameter greater than 6mm, excluding appendiceal perforation and appendiceal tumors. For pregnant women, children, and patients planning pregnancy who refuse CT scans, colonoscopy can be combined to confirm appendicitis, with endoscopic findings including mucosal edema and the presence of pus or fecaliths at the appendiceal orifice[7]. Acute appendicitis is classified into acute simple appendicitis, acute suppurative appendicitis, acute gangrenous and perforated appendicitis, and inflammatory masses or periappendiceal abscesses formed by omental wrapping[5]. Clinically, acute simple appendicitis and acute suppurative appendicitis are collectively referred to as acute uncomplicated appendicitis; gangrenous and perforated appendicitis or those with periappendiceal abscesses are collectively referred to as acute complicated appendicitis[8].

Traditional treatments for appendicitis include conservative antibiotic therapy and appendectomy, the latter comprising open appendectomy (OA) and laparoscopic appendectomy (LA). Harris[9] performed the first OA in 1883. In 1983, Semm[10] completed the first LA, heralding a new era in appendectomy. For over a century,

appendectomy has been the primary treatment for acute appendicitis. However, appendectomy is associated with a series of complications such as wound infection, incisional hernia, intra-abdominal infection, intestinal obstruction, interstitial pneumonia, urinary tract infection, cardiovascular accidents, *etc*[11-13]. Excessive surgical treatment can also lead to negative appendectomies, with recent studies reporting rates as high as 8%-30%[14,15]. Studies have suggested controversy over the impact of appendectomy on the development of inflammatory bowel disease and Parkinson's disease[16,17], but an increasing number of studies indicate a possible positive correlation between appendectomy and colorectal cancer, gallstones, and cardiovascular disease[18-20].

Some scholars have proposed that the appendix is not a vestigial organ but can produce various immunoglobulins. Moreover, due to its unique shape and position, the appendix is considered a reservoir or safe house for intestinal microbiota, playing an important role in regulating the gut flora[21]. With the development of endoscopic minimally invasive technology, Liu *et al*[22] proposed the endoscopic retrograde appendicitis therapy (ERAT). Our team has developed an appendoscope, which has been successfully applied in clinical practice[23]. Both ERAT and the appendoscope can achieve the goal of treating acute appendicitis while preserving the appendix.

ERAT

Inspired by the clinical application of endoscopic retrograde cholangiopancreatography (ERCP), Liu *et al*[22] first proposed ERAT in 2012. The procedure is as follows: A colonoscope with a transparent cap at the tip is inserted into the cecum, using the transparent cap to push aside the Gerlach's valve at the appendiceal orifice, and the Seldinger technique is used for appendiceal cannulation; after successful cannulation, aspiration of the appendiceal lumen is performed to reduce luminal pressure; under X-ray guidance, a contrast agent is injected for appendiceal lumen imaging; appendiceal lumen irrigation and/or lithotripsy are performed; and a stent is placed for drainage. Liu *et al*[24] conducted a multicenter clinical study in 2015, involving 34 patients with a

definitive diagnosis of acute uncomplicated appendicitis, one of whom failed cannulation, resulting in a 97% success rate for ERAT. One patient (3%) underwent appendectomy due to perforation within 48 hours postoperatively, and there were no long-term complications at 12-month follow-up, while two patients (6.2%) underwent appendectomy due to recurrent abdominal pain.

To evaluate the clinical efficacy of ERAT compared to LA in the treatment of acute appendicitis, retrospective studies have been conducted. Yang *et al*[25] included 422 patients (ERAT 79; LA 343) and found that the cure rate within one year and the pain score 6 hours postoperatively in the ERAT group were significantly higher than in the LA group. Moreover, compared to the LA group, the ERAT group had significantly shorter median operative time and median hospital stay. There was no significant difference between the two groups in terms of median time to recurrence and incidence of adverse events at one year. Ding *et al*[26] divided 210 patients with acute appendicitis into ERAT, LA, and OA groups. The results showed that the operative time in the ERAT group was significantly shorter than in the LA and OA groups. The postoperative hospital stay, postoperative bed rest time, surgery-related complications, and hospitalization costs were all significantly lower in the ERAT group compared to the latter two groups.

To compare the efficacy of ERAT with antibiotic treatment for acute uncomplicated appendicitis, Li *et al*[27] conducted a multicenter retrospective study. By comparing treatment success rates, median hospital stays, pain relief rate within 24 hours, and one-year follow-up recurrence rate, the ERAT group outperformed the antibiotic group. This may be because fecaliths, the most common cause of acute appendicitis, can be endoscopically removed during ERAT, and a stent can be placed to relieve luminal pressure. Pata *et al*[28] conducted a meta-analysis comparing ERAT with appendectomy or antibiotic treatment for acute uncomplicated appendicitis. The results showed no significant differences in technical success rates and one-year follow-up treatment efficacy among the three, but ERAT had advantages in postoperative pain relief and hospital stay duration.

ERAT is an effective minimally invasive alternative for treating uncomplicated acute appendicitis. However, current clinical studies are mostly from China. To further evaluate the safety and efficacy of ERAT, a comprehensive, international, multicenter, randomized controlled prospective study is urgently needed.

NON-X-RAY-ASSISTED ERAT FOR SPECIAL POPULATIONS WITH ACUTE UNCOMPLICATED APPENDICITIS

The ERAT procedure requires X-ray assistance, which carries a certain radiation risk. There have been successful cases of ERAT performed without X-ray assistance. Kang *et al*[29] used contrast-enhanced ultrasound instead of endoscopic retrograde appendiceal imaging in a prospective, randomized controlled trial to compare the efficacy of modified ERAT (mERAT) with antibiotic treatment for children with acute uncomplicated appendicitis. The results showed that the overall success rate of mERAT treatment (100%) was significantly higher than that of antibiotics (80.9%). The median discharge time in the mERAT group was significantly shorter than that in the antibiotic treatment group (6.00 days ± 1.76 days). mERAT provides a new treatment option for children with acute uncomplicated appendicitis. Liu *et al*[30] reported a case of a pregnant woman at 18 weeks of gestation with acute appendicitis who successfully completed ERAT without anesthesia and X-ray assistance. The patient's abdominal pain was immediately relieved postoperatively, and the pain was completely relieved the next day. The patient was discharged quickly without antibiotic treatment during hospitalization. Thus, non-X-ray-assisted ERAT is an effective treatment method for special populations such as children or pregnant women with acute appendicitis.

ERAT FOR ACUTE COMPLICATED APPENDICITIS

Although ERAT is not routinely used for treating acute complicated appendicitis, there have been successful clinical case reports to date. Song *et al*[31] reported a case of a 73-year-old elderly woman diagnosed with periappendiceal and subhepatic abscesses. Due to poor baseline conditions and no surgical indications after multidisciplinary

discussions, the patient underwent ERAT with stent placement. Follow-up CT after 2 months showed no abscess, and there was no recurrence after 6 years of follow-up. Li *et al*[32] reported a case of a 34-year-old woman diagnosed with acute appendicitis complicated by a giant appendiceal abscess and intestinal obstruction. The patient underwent ERAT with stent placement, and the intestinal obstruction was relieved postoperatively. A follow-up CT after 2 months showed complete resolution of the abscess. Cui *et al*[33] from our team performed ERAT on 9 patients diagnosed with appendiceal abscesses, and the patients had good prognoses postoperatively. Therefore, ERAT is an effective treatment method for periappendiceal abscesses, but more extensive clinical studies are needed to confirm this.

FUNNEL-HOOD-ASSISTED ERAT

Cheng *et al*[34] performed ERAT using an independently developed funnel-shaped hood with a small-diameter tip. A 33-year-old male patient diagnosed with acute appendicitis experienced immediate relief of abdominal pain symptoms after undergoing Funnel-hood-assisted ERAT, and the patient was discharged three days later. Funnel-hood-assisted ERAT is a technological innovation that can reduce the difficulty of cannulating the appendiceal lumen, and it is expected to improve the success rate of ERAT treatment and promote its clinical application.

SPY-GLASS DS ASSISTED ERAT

The SpyGlass DS is a second-generation cholangioscopy system with an outer sheath diameter of 3.3 mm, equipped with one biopsy channel (diameter 1.2 mm), one fiber optic channel (1.0 mm), and two irrigation channels. It allows direct visualization of the biliary tract and is used for the diagnosis of biliary and pancreatic duct strictures, treatment of difficult stones, and radiofrequency ablation of cholangiocarcinoma. The procedure can be completed without the need for X-ray or ultrasound guidance.

Kong *et al*[35] reported on 14 cases of acute uncomplicated appendicitis treated with SpyGlass DS-assisted ERAT, achieving a 100% success rate. The average operation time

was 37.8 minutes ± 22.0 minutes. All patients experienced immediate postoperative relief of abdominal pain. The average postoperative hospital stay was 1.9 days ± 0.7 days. No recurrences were observed during a follow-up period of 2 months to 24 months. Additionally, Kong *et al*[36] successfully performed SpyGlass DS-assisted ERAT on a patient diagnosed with acute appendicitis at 14 weeks + 2 weeks of pregnancy without anesthesia, and the patient eventually gave birth at full term. Similarly, Wang *et al*[37] performed ERAT using a digital single-operator cholangioscopy system in a pregnant woman. The patient's abdominal pain was significantly relieved postoperatively, and she was discharged without antibiotics. SpyGlass DS-assisted ERAT is a safe and effective alternative for diagnosing and treating acute uncomplicated appendicitis, providing a treatment option for special populations such as pregnant women who need to avoid or refuse X-ray exposure.

APPENDOSCOPIC TREATMENT OF ACUTE APPENDICITIS

Inspired by the SpyGlass DS, our team has successfully developed an appendoscope specifically designed for the diagnosis and treatment of appendiceal diseases, which has passed ethical review and clinical trials and obtained a national patent. The appendoscope is a disposable digital imaging system operated through the biopsy channel of a colonoscope; it is equipped with an LED light source system and has two models with outer sheath diameters of 3.3 mm or 2.6 mm, featuring a biopsy channel (diameter 2.0 mm or 1.2 mm) and two irrigation channels. The distal end of the outer sheath can be adjusted in multiple directions for ease of operation. The appendoscope avoids complications related to X-rays and contrast agents and provides more accurate and intuitive observation under direct endoscopic vision, which is more conducive to the diagnosis and treatment of appendicitis. Compared to the SpyGlass DS, the appendoscope has a more stable imaging system, wider biopsy and irrigation channels, and a price of around 5000 RMB, which is significantly more affordable than the former (approximately 12000 RMB domestically).

Appendoscope Procedure: Patients undergo bowel preparation 6 hours before the procedure with 3.0 L of polyethylene glycol electrolyte solution or 1.5 L of lactulose solution to cleanse the bowel. For patients with clinical symptoms of nausea and vomiting or unable to cooperate with oral laxatives, five 500 mL saline enemas are administered 30 minutes before the procedure. All patients receive intravenous general anesthesia and are positioned supine. A colonoscope (Olympus 290 or Fuji 7000) with a transparent cap is inserted into the cecum, and the appendoscope is advanced through the biopsy channel of the colonoscope into the appendiceal lumen to observe the interior, perform irrigation, stone retrieval, and other treatments as needed. If a fecalith is seen obstructing the appendiceal orifice, stone retrieval treatment can be performed first (Figure 1).

The first clinical application of the appendoscope was reported in June 2022 and published in the top international endoscopy journal, Endoscopy. A 73-year-old female patient was diagnosed with chronic appendicitis. We observed a fecalith obstructing the appendiceal orifice *via* colonoscopy. After removing the fecalith with a retrieval basket, we inserted the appendoscope to observe the appendiceal lumen, where mucosal congestion and edema were visible, with no residual fecalith. The patient experienced significant relief of abdominal pain postoperatively, with no related complications occurring. She was discharged one week later and has had no recurrence to date[23]. The clinical application of the appendoscope for acute uncomplicated appendicitis has been completed in two cases. Both young patients were admitted with abdominal pain and underwent appendoscopic examination after CT imaging suggested appendicitis. One patient had a fecalith removed, and both were discharged within two days postoperatively without complications and had no recurrence during follow-up (Table 1).

The appendoscope has achieved minimally invasive treatment of appendicitis, shortened hospital stay, and saved medical costs, with favorable patient outcomes. Future large-scale clinical studies are still needed to verify the feasibility, safety, and efficacy of appendoscopic treatment for acute appendicitis, providing clinical

experience on how to improve the success rate of treatment for acute appendicitis and reduce the incidence of complications.

CONCLUSION

With the booming development of endoscopic minimally invasive technology, the application of ERAT and related new technologies has provided us with a new perspective on the treatment of acute appendicitis. Based on the use of biliary endoscopy systems from ERCP and considering endoscopic costs, we have developed the appendoscope and successfully applied it in the treatment of appendicitis. The appendoscope has the following advantages: (1) Direct insertion into the appendiceal lumen allows for more precise and intuitive operation under direct vision; (2) Avoidance of X-ray and contrast agent hazards; (3) Short operation time, short hospital stay, and fewer postoperative complications; and (4) Low cost, reducing the economic burden on patients. However, due to the small sample size, the study has certain limitations. We will increase the sample size in the later stage for further validation. The application of the appendoscope is not limited to the diagnosis and treatment of appendicitis. Currently, we are developing specialized biopsy forceps, stents, and other accessories for the appendoscope, which is expected to become an important tool in the diagnosis and treatment of benign and malignant appendiceal diseases.

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Figures and Tables

Figure 1 Appendoscope treatment. A: Fecalith obstructing the appendiceal orifice; B: A retrieval basket enters the appendiceal lumen; C: Removal of fecalith with the retrieval basket; D: Insertion of the appendoscope into the appendiceal lumen; E: Images of the appendiceal lumen; F: Pus and localized mucosal congestion and edema.

Table 1 One patient had a fecalith removed, and both were discharged within two days postoperatively without complications and had no recurrence during follow-up

Patient ID	Gender	Age (years)	Chief complaint	Operation time (minutes)	Appendiceal lumen fecalith	Abdominal pain relief time (days)	Hospital stays	Follow-up time (months)	Complications
1	Female	17	Abdominal pain for 3 days	35	Yes	1	2	13	None
2	Male	24	Abdominal pain for 2 days	32	No	1	1	12	None

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