

Advantages of gasless single-port transumbilical extracorporeal laparoscopic-assisted appendectomy in the treatment of uncomplicated acute appendicitis in children in China: a multi-institutional retrospective study

Jian-Hua He¹, Yi-Peng Han², Tian Hang³, Zhi-Cai Lin³, Shi-Jiao Lu³,
Jian-Feng Wang³ and Zhi-Hua Hong³

¹Department of Pediatric Surgery, The Affiliated Hospital of Medical School, Ningbo University, Ningbo, China

²Department of Neurosurgery, Children's Hospital of Fudan University, National Children's Medical Center, Shanghai, China

³Department of Pediatric Surgery, Women and Children's Hospital Affiliated, Jiaying University, Jiaying, China

ABSTRACT

Gasless transumbilical extracorporeal laparoscopic-assisted appendectomy is an approach used increasingly to treat uncomplicated acute appendicitis (UAA). However, there is limited information on its clinical effects and value in the Chinese pediatric population. This study retrospectively reviewed patients with UAA treated in two pediatric institutions from January 2018 through October 2021. Enrolled patients were divided into two groups by operative technique: gasless transumbilical laparoscopic-assisted appendectomy (gasless-TULAA, n=142) and conventional laparoscopic appendectomy (CLA, three-port, n=126). The perioperative clinical data, including age, sex, body mass index (BMI), operation time, time to postoperative ambulation, time to first postoperative exhaust, hospitalization expenses, and postoperative complications (incision infection, intestinal obstruction, and residual abdominal abscess), were compared between the two groups. Operations in both groups were successfully conducted without converting to open surgery. There were no significant differences ($p > 0.05$) in age and BMI in the two groups. Compared with CLA, gasless-TULAA showed significantly shorter operation time, earlier postoperative ambulation, shorter postoperative exhaust time, and lower hospital cost ($p < 0.001$). All patients were followed for 3 months, and postoperative complications were observed in three patients: two patients in the gasless-TULAA group (one with surgical wound effusion, one with intra-abdominal abscess), and one patient in the CLA group (surgical wound infection); there was no significant difference between the groups. Notably, 38 patients initially treated by gasless-TULAA were converted because of intraoperative factors. The gasless-TULAA technique had potential benefits: shortened operation time, better outcome, and greater cost-efficiency. These superiorities are worthy of future large-scale prospective study.

Keywords: uncomplicated acute appendicitis, gasless transumbilical single-port laparoscopic-assisted appendectomy, 3-port laparoscopic appendectomy, children

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Corresponding Author: Zhi-Hua Hong, MD

Department of Pediatric Surgery, Women and Children's Hospital Affiliated, Jiaying University,
East Zhong Huan Road, No. 2468, Jiaying, Zhejiang 314050, China

Tel: +86-573-83963131, E-mail: hongzhihua@zjxu.edu.cn

Abbreviations:

UAA: uncomplicated acute appendicitis

gasless-TULAA: gasless transumbilical laparoscopic-assisted appendectomy

CLA: conventional laparoscopic appendectomy

BMI: body mass index

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INTRODUCTION

Acute appendicitis (AA) is an ancient disease with a history of approximately 300 years.¹ As one of the most common general surgical emergencies, AA has an incidence as high as 90 to 100 per 100,000 persons per year, with a lifetime risk of 7–8%.² The peak age of AA is 10–19 years³; therefore, AA is a mainstay of pediatric surgeons' clinical practice.

Treatments of AA primarily include nonoperative antibiotic-based therapy and surgical treatment. Randomized studies on uncomplicated acute appendicitis (UAA) revealed the advantages of nonoperative treatment, while risk for treatment failure increased in patient with an appendicolith, and approximately 40% of children who received antibiotics alone suffered from recurrence in 5 years.⁴⁻⁷ In China, a nationwide study showed a significantly higher success rate (100.0% vs 96.8%) in the surgical group than in the nonoperative group in children with UAA, and the 1-year recurrence rate in the nonoperative group was 17.3%.⁸

Surgical management of UAA includes the open approach and laparoscopic appendectomy, although there remains controversy regarding the advantages of the laparoscopic approach as far as the low occurrence of postoperative complications and shorter duration of hospitalization.^{2,9,10} With progress in surgical technique, most of the surgeons in the US and Europe choose laparoscopic appendectomy for UAA, and the major approach was the conventional three-port, followed by the two- and single-port approaches.^{2,11} Although there were various opinions on the new approach of single-port laparoscopic appendectomy, the advantages of cosmetic outcome and cost-effectiveness were repeatedly reported, compared with the traditional three-port approach.¹²⁻¹⁴ In China, gasless single-incision laparoscopic appendectomy was first reported in 2011, although the technique was used first in adult UAA and the incision was made at McBurney's point.¹⁵ Later, transumbilical single-incision laparoscopic appendectomy was introduced and reported by several groups in China. It was regarded as a feasible, safe, cost-effective, and cosmetic approach in adults and children with UAA.¹⁶⁻¹⁹ Although gasless transumbilical laparoscopic appendectomy, the combined surgical technique, was increasingly reported in adults and children with UAA, there was limited information about this approach in Chinese children.²⁰⁻²³ Here we report our multicenter retrospective study of gasless transumbilical extracorporeal laparoscopic-assisted appendectomy (gasless-TULAA) in treating UAA in children, in assessing this approach in the Chinese pediatric population.

MATERIALS AND METHODS

Patients and enrollment

This retrospective study recruited patients with UAA who underwent gasless-TULAA or conventional three-port laparoscopic appendectomy (CLA), from January 2018 to October 2021, in Women and Children's Hospital Affiliated to Jiaxing University and in The Affiliated Hospital of Medical School of Ningbo University. The perioperative clinical data, including age, sex, body

mass index (BMI), operation time, time to postoperative ambulation, time to first postoperative exhaust, hospitalization expenses, and postoperative complications (incision infection, intestinal obstruction, and residual abdominal abscess), were retrieved. The study was approved by the Institutional Review Boards of the participant facilities in accordance with Declaration of Helsinki and its later amendments (KY20210717 of The Affiliated Hospital of Medical School of Ningbo University, 2020-30 of Women and Children's Hospital Affiliated to Jiaxing University). The inclusion criteria were defined as: (1) patients younger than 16 years at admission; (2) UAA diagnosed through clinical presentation, blood tests, ultrasonography, and/or CT scan according to routine clinical practice⁹; (3) either gasless-TULAA or CLA were conducted as the initial treatment within 12 hours after admission. Exclusion criteria were: (1) history of appendicitis, laparoscopic surgery, or absolute contraindication to laparoscopic surgery; (2) intraoperative diagnosis of appendicitis other than UAA; (3) contraindication to general anesthesia; (4) generalized peritonitis or shock on admission; (5) disease duration longer than 72 hours or confirmed appendiceal abscess; (6) patients initially treated with gasless-TULAA or CLA but converted to any other procedure during the operation. The use of preoperative antibiotics was not an exclusion condition.

Surgical methods

All patients were treated by the same surgical teams and techniques at participant sites. Patients were encouraged to empty their bladders and preoperative fasting and defecation were required before general anesthesia for the surgeries. Gasless-TULAA and CLA were performed by attendings in the participating institutions who had previously performed both approaches in over 100 patients, especially, at least 5 cases by gasless-TULAA. Both procedures were conducted as routine clinical practice and the approach was selected at the discretion of the surgeons. Instruments used in either procedure were the Stryker pediatric laparoscope and visualization system (Stryker China, Ltd., Taikoo Shing, Hong Kong). A 4-cm diameter disposable incision holder (Wuxi Tongda Medical Treatment Electrical Appliances Co, Ltd, Jiangsu, China) was attached to the incision in the gasless-TULAA procedure.

Gasless-TULAA was modified according to the technique described in previous reports.^{20,21,23} Briefly, after the general anesthesia was administered with the patient in the supine position, an approximately 2.0 to 2.5 cm longitudinal incision was made through the umbilicus. The fascia and peritoneum were opened under direct vision, and the absence of bowel or omental adhesions around the incision was confirmed. The incision holder was placed through the umbilical incision (Fig. A), and an assistant used a surgical retractor to lift the abdominal wall and provide a working space in the peritoneal cavity. A 30-degree laparoscope and 3-mm or 5-mm laparoscopic forceps were inserted through the holder with the patient placed in the Trendelenburg position and rotated to the left by 15–20 degrees. Once the appendix was identified and dissociated from adhesions, it was exteriorized through the umbilicus and resected in an open procedure (Fig. B). The stump was then returned to the abdomen and any residual intra-abdominal fluid was aspirated followed by routine closure (Fig. C).

CLA was performed as a standard laparoscopic appendectomy using a 10mm laparoscopic trocar in the umbilicus and two 5-mm ports in the left mid abdomen and left suprapubic area.

Perioperative antibiotics and other medications were administered in both procedure groups as routine practice.

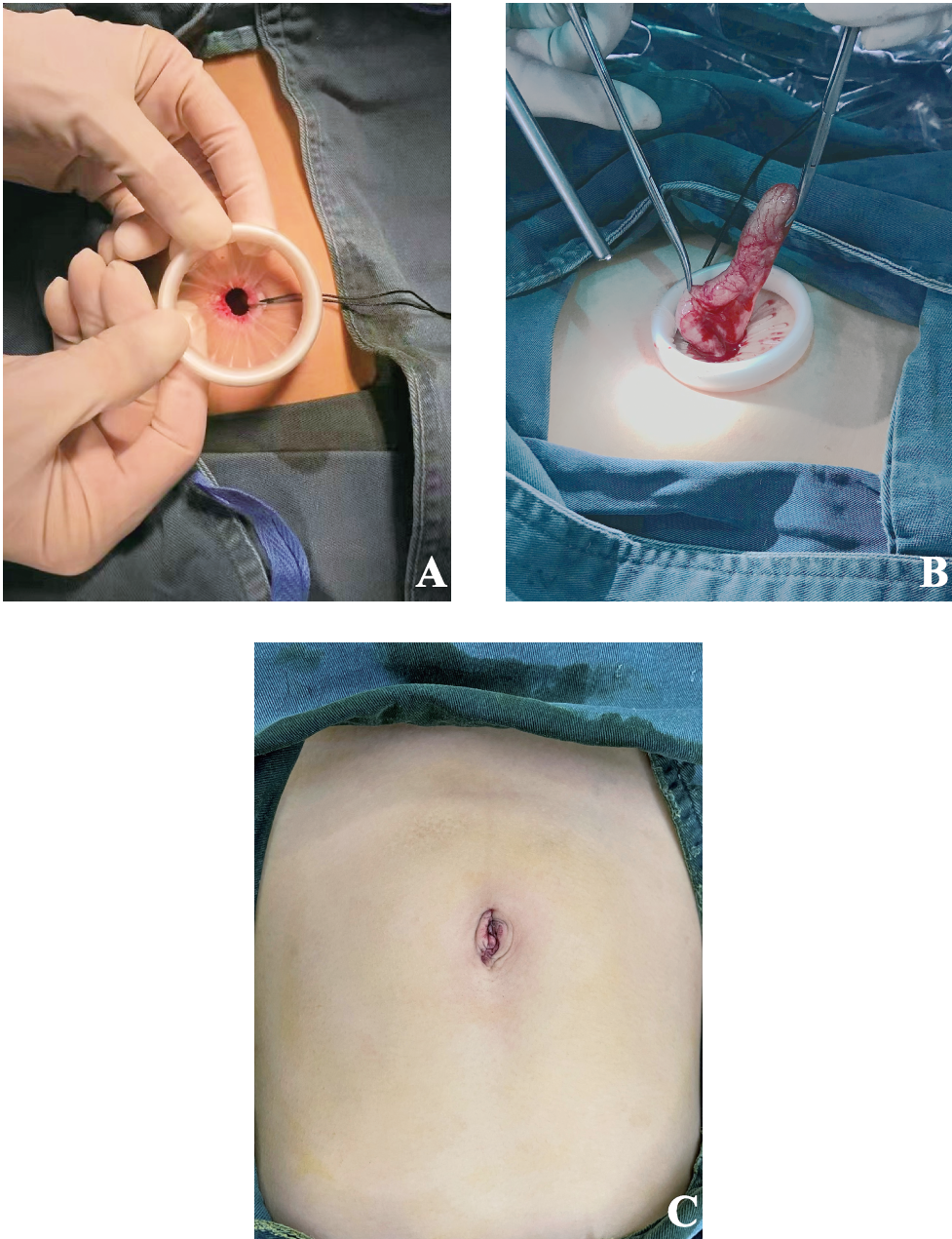


Fig. Surgical maneuvers in gasless-TULAA

Fig. A: The disposable incision holder is attached through umbilical incision.

Fig. B: Exteriorized appendix in the procedure.

Fig. C: Closure of the scarless umbilicus wound.

Statistical methods

Continuous variables were described as mean with standard deviation and were tested using Student's t-test. Qualitative data were tested by Pearson's chi-squared test and Fisher's exact test. All data were analyzed using Statistical Analysis System (SAS) software. In this study, $p < 0.05$ was considered statistically significant.

RESULTS

Patient characteristics

During the study period of January 2018 through October 2021, there were 306 patients with UAA at the participating sites; no open surgeries were performed in these children. Thirty-eight patients initially treated with gasless-TULAA procedures were converted to the CLA approach because of intraoperative conditions: dense, immobile adhesions between the appendix and surrounding tissues were found in 18 patients, and 20 patients failed in exteriorization of the appendix because of obesity. There were 268 patients with UAA enrolled in this study, with 142 cases (68 males and 74 females) in the successful gasless-TULAA group and 126 cases (61 males and 65 females) in the CLA group. The mean age was 11.3 ± 3.4 years in the gasless-TULAA group and 10.6 ± 3.2 years in the CLA group. The mean body mass index (BMI) was 16.5 ± 2.2 kg/m² in the gasless-TULAA group and 16.8 ± 2.0 kg/m² in the CLA group. There were no significant differences in patient sex, age, and BMI between the gasless-TULAA and CLA groups (Table).

Table Comparison of clinical characteristics and treatment factors between the 2 surgical approaches

Characteristics/Factors	Group; mean \pm SD or no. (%)		<i>p</i> value
	Successful TULAA Group (n=142)	CLA Group (n=126)	
Age (years)	11.3 \pm 3.4	10.6 \pm 3.2	0.085 ^a
BMI (kg/m ²)	16.5 \pm 2.2	16.8 \pm 2.0	0.246 ^a
Gender			
Male	68 (47.89%)	61 (48.41%)	0.932 ^b
Female	74 (52.11%)	65 (51.59%)	
Operation time (mins)	28.5 \pm 10.5	42.5 \pm 10.7	<0.001 ^a
Time for postoperative ambulation (hours)	8.5 \pm 1.5	12.5 \pm 2.0	<0.001 ^a
Postoperative exhaustion time (hours)	10.5 \pm 5.5	16.8 \pm 6.8	<0.001 ^a
Hospitalization expenses (RMB)	6290.5 \pm 58.5	7381.5 \pm 60.5	<0.001 ^a
Postoperative complications	2 (1.41%)	1 (0.79%)	>0.999 ^c
Surgical wound effusion	1	0	/
Intra-abdominal abscess	1	0	/
Surgical wound infection	0	1	/

TULAA: transumbilical extracorporeal laparoscopic-assisted appendectomy

CLA: conventional three-port laparoscopic appendectomy

BMI: body mass index

**p* values: a=Student's t-test, b=Chi-square test, c=Fisher's exact test.

Difference in surgical procedures and outcomes

The mean operation time of gasless-TULAA was 22.5 ± 10.5 minutes, compared with 42.5 ± 10.7 minutes in CLA; TULAA was significantly shorter. Patients in the gasless-TULAA group had significantly earlier postoperative ambulation and shorter postoperative exhaust time, than those in the CLA group (8.5 ± 1.5 hours vs 12.5 ± 2.0 hours, and 10.5 ± 5.5 hours vs 16.8 ± 6.8 hours). The mean hospital cost in patients with gasless-TULAA was 6290.5 ± 58.5 RMB, which was significantly lower than that of CLA at 7381.5 ± 60.5 RMB.

During the follow-up period, three patients developed postoperative complications. There were two patients in the gasless-TULAA group: one with surgical wound effusion and one with an intra-abdominal abscess. One patient in the CLA group developed a surgical wound infection. All patients with complications were treated with antibiotics and recovered. There was no significant difference in postoperative complication rates between the gasless-TULAA and CLA groups. (Table)

DISCUSSION

Because the equipment and techniques of laparoscopic surgery have greatly improved, an increasing number of surgeons in the US, Europe, and Asia are adopting laparoscopic-assisted appendectomy instead of open surgery in treating UAA.⁸⁻¹¹ Single-incision laparoscopic appendectomy, a novel approach of laparoscopic-assisted appendectomy, was introduced into practice around 2010. Because of limited benefits and huge variability in technique in different regions compared with CLA in early reports, the new technique did not achieve wide acceptance at first.²⁴⁻²⁶ Recently, there are increasing numbers of reports showing the advantages of single-incision laparoscopic appendectomy in treating UAA, especially in cosmetic outcome and recovery time,²⁷⁻²⁹ which attracted surgeons' interest and attention to this type of approach.

It was not until 2011 that gasless-TULAA was introduced—practically simultaneously—by Japanese and Korean surgeons, revealing the feasibility, safety, and cost-effectiveness of the procedure.^{30,31} As a modified TULAA technique, gasless-TULAA was an approach more feasible for pediatric rather than adult UAA because the distance of base of the appendix to the umbilicus is increased in adults, and the abdominal wall is much more flexible in children. These factors make it easier to exteriorize the appendix through the umbilical incision in children. Exteriorization of the appendix is the most important step in the procedure.^{14,15} Furthermore, pneumoperitoneum-related complications such as significant hemodynamic changes, increased intracranial pressure, and thromboembolism³² could be avoided in this approach.

In the increasing reports on gasless-TULAA, the median operation time was approximately 30.4–59 minutes.^{20-22,33} In this study, we found that there was significantly shortened operation time in the gasless-TULAA procedure (28.5 minutes, compared with 42.5 minutes in CLA). Because varying results in time and cost between the single-incision and three-port approaches published in the literature^{19,28,29,34,35} were blamed on the learning curve,³⁶ the advantage of a shorter operation time in gasless-TULAA could be achieved by experienced surgeons. The major time-consuming steps in CLA were the insertion of two additional trocars, the interchange of instruments multiple times for intraperitoneal appendectomy, and the closure of two additional incisions.²⁹ The gasless-TULAA approach could directly create the surgical space by lifting the abdominal wall through incision holder. In our experience, the intraoperative muscle relaxation for a less-invasive elevation of the abdominal wall, flexible patient position adjustment for easier exposure of the appendix, and full separation of peripheral tissues such as the omentum adherent to the appendix, were three major benefits to the operation.

Postoperative outcomes of gasless-TULAA were significantly better than CLA in this study, with earlier postoperative ambulation and shorter postoperative exhaust time. These results are consistent with the published literature,^{31,37} which provided strong evidence in confirming the benefits of gasless-TULAA. Moreover, the costs of gasless-TULAA were significantly lower than those of CLA, which had been confirmed in many report—not only in gasless-TULAA, but also in conventional TULAA.^{21,29,31,34} The postoperative complications that occurred in this study showed no statistical significance between the two groups, and they are commonly seen in children with UAA.³⁸

Although the cosmetic outcome and postoperative pain were not investigated in this study, ample reports describe superior long-term cosmetic satisfaction with the TULAA approach as well as equal or reduced postoperative pain, in comparison with CLA.^{18,27,28,39} In addition, our postoperative follow-up revealed scarless wounds in children treated with gasless-TULAA. We observed no significant difference in patient BMIs between the two procedures in this study.

It was interesting to note that gasless-TULAAAs were mainly reported in Japan, China, and Korea. There is only one study from Jordan, which still focused on the Asian population.⁴⁰ It was also worth to emphasize that the conversion rate of gasless-TULAAAs to CLA was 21.1% in our study. Although the conversion rates in previous studies on procedure of TULAA with or without gas were ranged from 8% to 39%, and the converted cases were not included in comparisons or even not mentioned in the reports.^{29,33,40} This was an alarming signal of possible failure in the gasless-TULAA for pediatric UAA in some specific conditions. The limitations of this study were not only the exclusion of these converted cases, but also the bias in non-randomized comparison. These defects should be further ameliorated in future studies.

CONCLUSIONS

This is the first retrospective study on the gasless-TULAA approach in treating children with UAA in China. Our data suggested the benefits of shortened operation time, fast postoperative recovery, and cost-efficiency, of gasless-TULAA, in comparison with CLA. Further large-scale, prospective studies are necessary.

AUTHOR CONTRIBUTION

JH He and YP Han shared co-first authorship and contributed equally to this work.

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CONFLICT OF INTEREST

The authors declare that they have no conflicts of interest.

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