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Original Article

Single-Site Laparoscopic-Assisted Appendectomy for Uncomplicated Appendicitis in Children: A Protocolised Approach with Enhanced Recovery and Same-Day Discharge

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Abstract

Background: Single-site laparoscopic-assisted appendectomy (SLA) is an emerging minimally invasive option for managing paediatric appendicitis. Its integration with enhanced recovery after surgery (ERAS) protocols and same-day discharge remains underexplored in younger children.

Methods: A retrospective review was conducted of children aged 1–12 years who underwent appendectomy at a single centre from January 2020 to December 2024. Patients who received SLA with histologically confirmed appendicitis were included. Outcomes assessed included operative time, complications, postoperative pain control, readmission, and discharge timing.

Results: Of 82 children with appendicitis, 26 underwent SLA and met study criteria. Most operations (73%) were performed by trainees under senior supervision. The mean operative time was 33 minutes. No intraoperative or postoperative complications occurred. Same-day discharge was achieved in 73% of patients, and all recovered with opioid-free analgesia. Readmissions were infrequent and unrelated to surgical issues.

Conclusion: SLA, when implemented within a structured ERAS protocol, is a safe and effective approach for uncomplicated paediatric appendicitis. It enables same-day discharge and facilitates excellent recovery with minimal morbidity. The technique is also suitable for trainee participation under supervision and offers advantages in operative time, cost, and cosmesis.

Keywords: *Paediatric appendicitis, Single-site laparoscopic-assisted appendectomy, Minimally invasive surgery, Enhanced Recovery After Surgery (ERAS), Same-day discharge*

Introduction

Appendectomy is one of the most frequently performed emergency surgical procedures in paediatric populations. While the conventional three-port laparoscopic appendectomy (LA) remains the standard approach, alternative minimally invasive techniques, such as single-site laparoscopic-assisted appendectomy (SLA), have gained increasing attention for their potential benefits in children, including improved cosmesis, reduced pain, and shorter hospital stays.

SLA combines the advantages of laparoscopy with the simplicity of extracorporeal appendectomy through a single transumbilical incision. Originally described in the late 1990s, [1,2] SLA avoids the need for multiple trocars and energy devices while enabling rapid recovery and minimal scarring. Several studies have since demonstrated its safety and effectiveness, positioning SLA as a viable option for selected paediatric patients with uncomplicated appendicitis. [3,4]

Enhanced Recovery After Surgery (ERAS) protocols have further revolutionised perioperative care in children, offering structured, evidence-based guidelines to improve recovery times, minimise complications, and promote early discharge. [5] Key elements of paediatric ERAS include opioid-sparing analgesia, early mobilisation, rapid reintroduction of oral feeding, and clearly defined discharge criteria. Despite its growing adoption, few studies have assessed the implementation of ERAS principles in the context of SLA for paediatric appendicitis.

Another area of evolving interest is the role of SLA in surgical training. The feasibility and safety of trainee-performed laparoscopic appendectomy are well-established for standard techniques [6], but limited data exist on whether SLA can similarly be integrated into training without compromising outcomes.

This study aims to evaluate the feasibility, safety, and outcomes of SLA for children with uncomplicated appendicitis, incorporating a structured ERAS protocol and including procedures performed by trainees under senior supervision. Particular emphasis is placed on the rate and safety of same-day discharge, and the potential for SLA to serve as a suitable training procedure in paediatric surgical practice.

Aim and Methods

This study aimed to evaluate the outcomes and feasibility of single-site laparoscopic-assisted appendectomy (SLA) in children aged 0–12 years with uncomplicated appendicitis.

This study was conducted as a retrospective departmental audit using anonymised data, including all patients aged 0–12 years who underwent appendectomy between 1 January 2020 and 31 December 2024 at our institution. Patients who underwent SLA with histologically confirmed appendicitis were included. Exclusion criteria were conversion to a three-port laparoscopic appendectomy or a normal histopathological finding of the appendix.

Selection of patients for SLA:

Eligible candidates were children aged 1–12 years with uncomplicated appendicitis and without obesity. Initial diagnostic screening was performed using the Artificial Intelligence Paediatric Appendicitis Decision-tree (AiPAD) system [7, 8]. Upon confirmation of the diagnosis, the decision to proceed with SLA rather than the conventional three-port approach was based on clinical and anatomical suitability. Key selection criteria included the absence of abdominal distension, no palpable abdominal mass on examination under general anaesthesia, and a body mass index (BMI) below 22 kg/m^2. This BMI threshold was selected according to the WHO BMI-for-age growth reference standards and regional data from East and Southeast Asia [9, 10], approximating the upper limit of the overweight range in children under 13 years. This criterion was intended to minimise technical difficulties associated with increased abdominal wall thickness, which could compromise visibility and externalisation of the appendix.

Preoperative Care

Preoperative family counselling included a detailed explanation of the diagnosis, the available surgical options (single-site laparoscopic-assisted or conventional three-port appendectomy), anticipated intraoperative findings, and expected postoperative recovery, including the possibility of same-day discharge. Informed written consent was obtained after this discussion.

Patients were scheduled for surgery following standardised fasting guidelines: 8 hours for solid food, 6 hours for nourishing fluids, and 2 hours for clear fluids. During the fasting period, patients were maintained on intravenous dextrose-saline solution. Where necessary, preoperative rehydration was achieved using appropriate boluses of Ringer's lactate to ensure optimal fluid balance.

Surgical procedure:

All procedures were performed under general anaesthesia with prophylactic antibiotics administered (Metronidazole 15 mg/kg and Cefuroxime 50 mg/kg). Patients were placed in the supine position, prepared with surgical spirit, and draped accordingly. A vertical transumbilical incision was made along the umbilicus to access the peritoneal cavity. A 12 mm laparoscopic port was inserted, and carbon dioxide insufflation was established at 10–12 mmHg with a flow rate of 2.0–2.5 L/min. A Karl Storz HOPKINS Telescope was introduced to identify the appendix (*Figure 01*), aided by tilting the table to the right and placing the patient in the Trendelenburg position. Murky peritoneal fluid, when present, was aspirated using a 5 mm suction instrument through the telescope's working channel.

A 5 mm laparoscopic bowel grasper was inserted through the telescope to grasp the tip of the appendix (*Figure 02*). Mobility was assessed by mobilising the appendix toward the liver. Adhesions, if present, were carefully dissected by blunt separation of avascular adhesions or gentle peeling of the omentum. Once adequately mobilised, the appendix was externalised through the umbilical port (*Figure 03*). In cases where externalisation was difficult due to a distended appendix, the umbilical fascial incision was extended caudally by 5–10 mm to facilitate atraumatic delivery.

Extracorporeal appendectomy was then performed using the conventional open technique, ensuring complete mobilisation of the mesoappendix and secure ligation at the appendiceal base, with care to avoid leaving a long stump (*Figure 03*). The appendiceal stump was returned to the peritoneal cavity. The umbilical wound edges were disinfected with povidone-iodine, and the fascia and subcutaneous tissue were closed with interrupted absorbable sutures. A compression dressing was applied to the umbilicus (*Figure 04*).

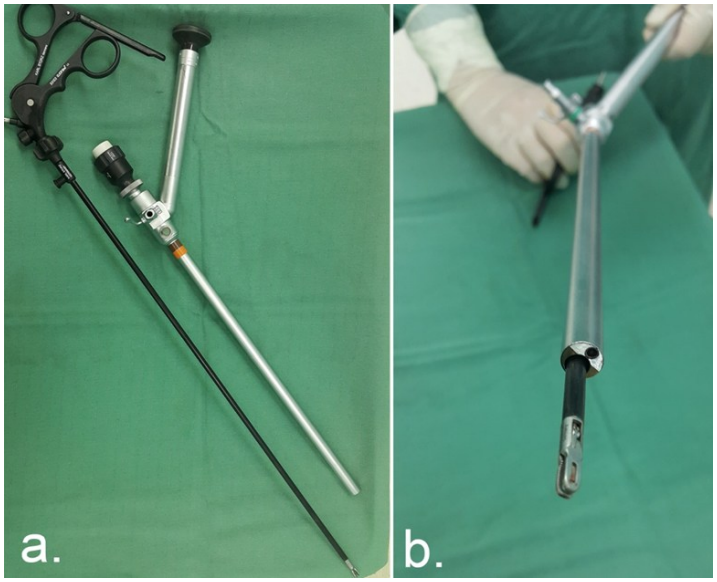

Figure 01. HOPKINS Telescope with retrieval grasper

(a) Karl Storz HOPKINS Telescope alongside the long 5 mm laparoscopic bowel grasper.

(b) The grasper is fully inserted through the working channel of the telescope, demonstrating the integrated setup used for appendix retrieval.

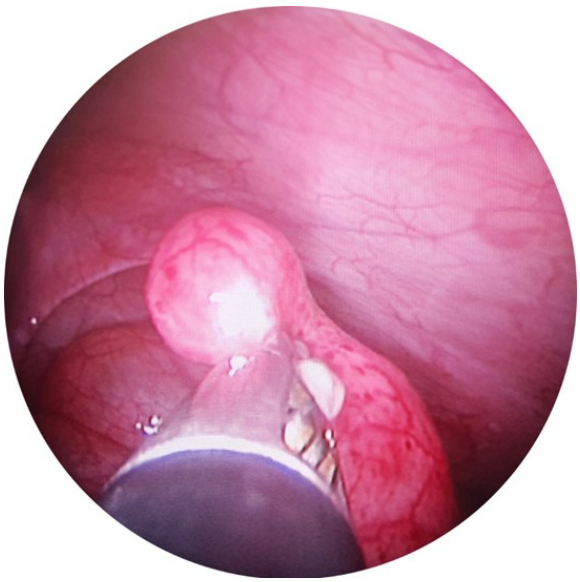

Figure 02. Grasping the tip of the appendix

The tip of the appendix is grasped using the 5 mm laparoscopic grasper introduced through the HOPKINS Telescope. The appendix is shown being elevated and directed toward the umbilical port in preparation for extracorporeal retrieval.

Figure 03. Extracorporeal appendectomy

The appendix is exteriorised through the umbilical incision with the base ligated. In this patient with a higher BMI (22.4 kg/m^2), antegrade dissection was performed from tip to base by sequentially ligating the mesoappendix to minimise tension and prevent mesenteric tearing.

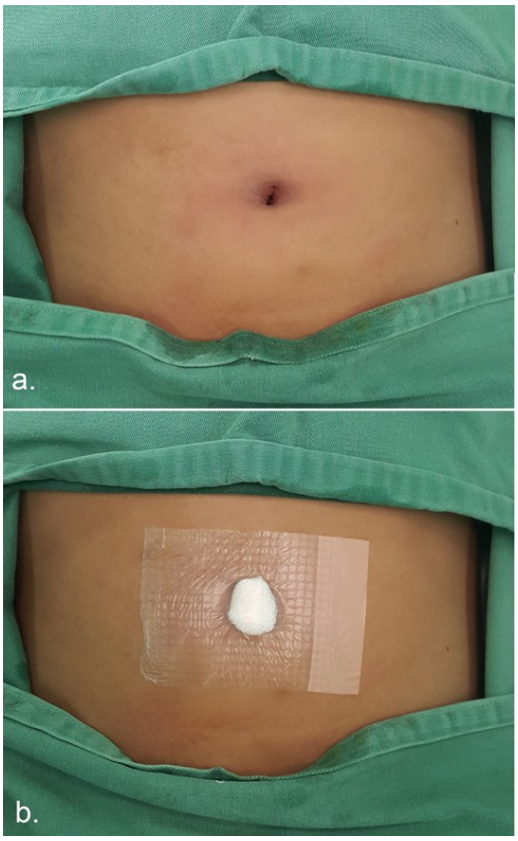

Figure 04. Umbilical closure and dressing

a. Umbilical incision following fascial and subcutaneous closure.

b. Compression dressing applied using gauze and adhesive over the umbilical wound.

Postoperative care and discharge protocol:

Postoperatively, patients were observed in the ward, encouraged to ambulate and permitted clear fluids after four hours. Diets were progressively advanced to soft and then regular foods, emphasising small, frequent meals while avoiding heavy, oily, or spicy items. Pain management included scheduled paracetamol (15 mg/kg four times daily), with ibuprofen (8 mg/kg) added as needed once oral intake was established.

Patients were observed for a minimum of 18 hours postoperatively. Discharge criteria included ambulation, tolerance of diet, and being afebrile. Persistent fever prompted initiation of intravenous cefuroxime and metronidazole until resolution, followed by oral antibiotics to complete a seven-day course. At discharge, caregivers received instructions on wound care, including keeping the dressing dry and removing it at home on postoperative day 5 after a warm shower. Signs of potential infection such as redness, swelling, or discharge were explained.

Families were also advised to maintain a soft diet for 3–7 days and gradually resume normal activities, with exemption from school physical education for two weeks. A hotline was provided for urgent concerns. In case of readmission, a standardised evaluation was performed including clinical examination, wound inspection, complete blood count with differential, C-reactive protein, and abdominal ultrasonography to exclude intra-abdominal collections or other complications.

Patients were reviewed in the surgical clinic at six weeks postoperatively and discharged thereafter unless further follow-up was clinically indicated. Long-term follow-up was conducted through the national unified health records system. Notably, our centre serves as the sole paediatric surgical unit in X country, a nation with a population of approximately 450,000, where paediatric patients are defined as individuals aged 0–12 years.

Results

Between January 2020 and December 2024, a total of 82 children were diagnosed with appendicitis. Of these, 29 patients met the eligibility criteria and underwent single-site laparoscopic-assisted appendectomy (SLA). Three patients were excluded from analysis: two due to intraoperative conversion to a standard three-port laparoscopic appendectomy (one for significant adhesions limiting appendix mobility and the other for pelvic appendicitis with purulent contamination suggestive of perforation), and one due to a normal histopathological finding of the resected appendix.

The final cohort comprised 26 patients (17 males, 9 females). The mean age was 9.7 ± 1.5 years, and the mean BMI was 18.5 ± 1.7 kg/m^2 (range, 14.9–21.5 kg/m^2). The mean operative time was 33.8 ± 8.3 minutes (range, 22–55 minutes). Most procedures (73%, 19 out of 26) were performed by surgical trainees under direct senior supervision. Operative times were slightly shorter for supervisors compared to trainees, with a mean duration of 29 minutes versus 36 minutes, respectively. No intraoperative or postoperative surgical complications were recorded, and no significant difference in outcomes was observed between cases performed by trainees and those performed by supervisors.

Same-day discharge was achieved in 19 patients (73%). Seven patients required extended hospitalisation, with a median length of stay of 3 days (range, 2–5 days). Reasons for delayed discharge included slow progression to oral intake in two patients, persistent parental concern about postoperative pain in one patient, and postoperative fever in three patients. One additional patient required a longer stay due to concomitant lower respiratory tract infection and an exacerbation of underlying asthma. The latter four patients received extended intravenous antibiotic therapy in hospital, followed by oral antibiotics to complete a 7-day course postoperatively.

Pain management was primarily achieved with paracetamol. Five patients (19%) required the addition of ibuprofen for breakthrough pain, with analgesia continued for a median of 2.5 days (range, 1–5 days). No wound site infections were observed.

Three patients required readmission following discharge. In all cases, clinical evaluation and imaging excluded intra-abdominal collections. The first patient was readmitted 10 days post-discharge with recurrent abdominal pain and normal laboratory findings and was managed conservatively. The same patient re-presented at 2 and 9 weeks with similar complaints and was subsequently diagnosed with functional abdominal pain, with psychosocial factors including recent parental separation. Management involved reassurance and family education. A further similar episode occurred 10 months later and was managed similarly. The second patient was readmitted with fever and an upper respiratory tract infection, confirmed by elevated white blood cell and neutrophil counts; they were discharged after 2 days on a 7-day course of oral co-amoxiclav. The third patient was readmitted 3 days after discharge with vomiting and was treated conservatively with intravenous hydration, ondansetron, and gradual reintroduction of oral feeding, and was discharged well after 2 days.

The minimum follow-up duration was 6 months, with a mean follow-up period of 22 months (range, 6–36 months). No patients required further abdominal surgical interventions during this period. Six patients were admitted during follow-up for unrelated abdominal conditions, including acute gastroenteritis (n = 4), gastritis (n = 1), and urinary tract infection (n = 1); all were managed conservatively without complications.

Discussion

Minimally invasive surgery has transformed the landscape of paediatric appendectomy. Single-site laparoscopic-assisted appendectomy (SLA), first introduced in the late 1990s [1,2], is increasingly recognised as a reliable alternative to conventional three-port laparoscopic appendectomy. This technique offers a combination of cosmetic appeal and reduced operative trauma by externalising the appendix through the umbilicus for extracorporeal removal [3]. Our findings affirm the safety, feasibility, and potential advantages of SLA in appropriately selected paediatric patients, while adding new insights into its integration within an enhanced recovery after surgery (ERAS) protocol [5].

In our cohort of children aged 1–12 years with uncomplicated appendicitis and BMI < 22 kg/m^2, SLA resulted in favourable outcomes: 73% achieved same-day discharge, no surgical complications were recorded, and opioid-free pain management was sufficient in all cases. This aligns with earlier studies demonstrating that SLA is associated with low complication rates and satisfactory cosmetic and functional results [3,4].

Importantly, our study incorporated a full ERAS protocol, including structured preoperative counselling, standardised fasting, opioid-free analgesia, early feeding, and defined discharge criteria. ERAS in paediatric surgery has shown benefits in reducing length of stay and complications, even in emergency settings [5,11,12]. The present study supports its applicability and effectiveness in the SLA context.

A key feature of our experience was the high success rate of SLA in procedures conducted by trainees under direct supervision. Trainees performed 73% of operations with no difference in outcomes or complication rates. This reflects previous findings by Esposito et al., who concluded that laparoscopic appendectomy is a safe procedure for trainees [6]. Our results extend this to SLA specifically, suggesting that its incorporation into training programs is feasible when proper case selection and oversight are ensured.

Patient selection was central to our approach. SLA was reserved for children without obesity or anatomical challenges. A BMI threshold of $<22\ kg/m^2$ was used based on WHO and regional growth data [9,10], reflecting the upper range of normal or mildly overweight children. This helped avoid technical challenges related to thick abdominal walls, which can limit safe externalisation of the appendix. The low conversion rate (7%) in our series supports the validity of this criterion.

The study also benefited from the use of an AI-supported diagnostic tool—the Artificial Intelligence Paediatric Appendicitis Decision-tree (AiPAD)—which was previously validated and locally implemented to improve diagnostic accuracy and standardise referrals [7,8]. While this was not directly evaluated in the present study, its role in preoperative decision-making may have enhanced selection quality and warrants further prospective exploration.

Same-day discharge was achieved in the majority of cases, with remaining patients requiring longer stays primarily due to non-surgical issues such as slow recovery of oral intake or comorbid infections. This matches findings from studies supporting same-day discharge following laparoscopic appendectomy in children without increased risk of readmission [11,12,13].

Three patients in our cohort were readmitted. None had intra-abdominal collections or required surgical intervention. One was later diagnosed with functional abdominal pain, illustrating the importance of psychosocial context in postoperative complaints. These findings reinforce the robustness of our discharge and follow-up strategy.

Our experience also highlights that the benefit of SLA extends beyond cosmesis. While eliminating additional trocar incisions is valuable, SLA also reduces operative time and cost by avoiding the use of multiple ports, energy devices, endobags, and endoloops. The extracorporeal ligation mimics the simplicity of open appendectomy, leading to shorter anaesthetic time and a more cost-effective workflow.

Beyond reaffirming the safety and feasibility of SLA, this study introduces practical refinements that enhance its clinical applicability. The use of an AI-assisted diagnostic tool for case selection, a clear anthropometric threshold to guide eligibility, and the demonstrated safety of trainee-performed SLA under supervision provide actionable insights for centres aiming to implement or expand SLA within an ERAS framework. These findings highlight the evolving intersection of technology, surgical education, and enhanced recovery in modern paediatric appendectomy.

Limitations

This study is limited by its retrospective design and modest sample size, which may affect the generalisability of the findings. Being a single-centre study, there is a potential for selection bias, particularly as the choice to perform SLA relied on clinical judgment and institution-specific protocols. Although a standardised BMI threshold and anatomical criteria were applied, these may not fully reflect patient diversity in broader settings. Additionally, the potential influence of the AI-based diagnostic support system (AiPAD) on case selection, while likely beneficial, was not independently evaluated. Future prospective, multicentre studies with larger cohorts and stratified comparisons are needed to validate these findings and further define the role of SLA within enhanced recovery frameworks in paediatric surgery.

Conclusion

This study demonstrates that single-site laparoscopic-assisted appendectomy (SLA), when applied to a carefully selected cohort of children with uncomplicated appendicitis, is a safe, efficient, and cost-effective technique. By integrating a structured ERAS protocol and utilising an AI-assisted diagnostic tool, we achieved high rates of same-day discharge with no surgical complications, minimal analgesic requirements, and successful trainee involvement. Beyond affirming the feasibility of SLA, our findings highlight its potential as a training-compatible, resource-efficient option within modern paediatric surgical practice. This reinforces SLA's suitability as a key component in enhanced recovery pathways and encourages its broader implementation under standardised protocols.

Conflicts of Interest

The authors declare no conflict of interest.

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