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Outcomes for open and laparoscopic appendicectomy for complicated appendicitis in children

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Background: The study aimed to compare the outcomes of paediatric laparoscopic appendectomy (LA) with open appendectomy (OA) for complicated appendicitis (CA). All trainees could perform OA without supervision.
Methods: This is a single-centre, retrospective, non-randomised review of children 4–12 years of age, who had either an OA or LA for CA. The data was collected from August 2012 to June 2016. Nineteen surgical trainees were initially supervised by a consultant until deemed able to perform LA safely. The on-call surgeon decided on operative approach. Intra- and postoperative complications were analysed. Primary endpoint was comparison of infection rates between groups, simultaneous differences between the two procedures performed by surgical trainees and consultants were evaluated.
Results: One hundred and fifty-five patients had appendicectomy for CA during the study period. Fourteen patients with incomplete information were excluded. Ninety had OAs and 51 LAs. Both groups were well matched demographically. Postoperative infective complications occurred in 13/51 (25.5%) of the LAs, and in 23/90 (25.6%) of the OA ($p = 0.159$). Fourteen trainees performed 27 LAs without consultant supervision by the conclusion of the study. The mean duration of LA surgery for surgical trainees was 110.35 minutes (IQR 22.5) and for consultants 93.87 minutes (IQR 35, $p = 0.497$).
Conclusion: There is no difference in intra- and postoperative complications between LA and OA for CA. Duration of surgery between surgical trainees and consultants were comparable. This indicates that surgical trainees acquire LA skill over a short period of time and that LA as a laparoscopic teaching procedure merits consideration.
Keywords: paediatric laparoscopic appendectomy, open appendectomy, complicated appendicitis

Background

With increasing experience with laparoscopic surgery in children, laparoscopic appendectomy (LA) has become an established surgical approach for complicated appendicitis (CA) (gangrenous perforated or necrotic appendicitis with or without local or diffuse peritonitis or abscess formation).[1-3] Several studies on LA for CA purport a decreased incidence of wound infection, reduced analgesia requirements, earlier oral intake, shorter hospitalisation and decreased incidence of bowel obstruction.[2-7] The advantage of a diagnostic laparoscopy where the diagnosis is unclear and an improved peritoneal lavage of all 4 quadrants under direct visualisation are other purported advantages. The increased incidence of postoperative intra-abdominal abscesses (IAAs) in a number of series remains a concern; this, however, shows large inter-study variance.[2,6,8] Initial equipment cost, and maintenance, longer set-up period when compared to open surgery and increased operating time are considered disadvantages.[9] The role of laparoscopic appendectomy for CA in children is, however, still undefined and lacks a randomised controlled trial.

Acute appendicitis in South Africa is still associated with high rates of morbidity and mortality. This is thought to be due to delayed presentation, with advanced disease and perforation often encountered in low- and middle-income countries (LMIC).[10,11] Delays in transportation as well as increased distances between referral centres add to this burden in the South African setting. A recent study to grade disease severity for acute appendicitis in children in KwaZulu-Natal reported an increased rate of complications associated with advanced disease that was more common than in high-income countries (HIC) series and a low rate of normal appendixes being removed.[10,11] In South Africa, the rate of paediatric LA is low.[10,11] Historically, patients presenting to our institution with CA were managed by open appendicectomy (OA). LA was introduced to our department in August 2012 based on the 2009 SAGES guidelines indicating that LA for CA was safe.[12] Similar to HICs, we experienced significant resistance at the introduction of LA as this type of surgery was perceived to have a considerably longer operating time, and nursing staff preferred open surgery due to their lack of familiarity with laparoscopic techniques in the emergency situation.

Traditionally, OA has been a common training operation for surgical trainees. Since its first introduction in 1983, LA has gained popularity as a minimally invasive procedure for the management of acute appendicitis.[2] Thus, OA as a training operation for surgical trainees has been replaced by LA. Only a few studies on the learning curve and safety for LA of CA in surgical trainees, from a South African perspective, are available.[13-15]

The aim of this study was to compare infective complications between OA and LA for CA, and to analyse the

effect of surgical experience and supervision on outcomes with the two operative approaches.

Methods

This is a single-centre, retrospective, non-randomised review from August 2012 to June 2016 of children aged 4–12 years, who presented with CA treated by appendectomy. All unstable patients requiring ICU were excluded, those with generalised peritonism were not excluded. CA was defined as an acute appendicitis associated with gangrene/necrosis, perforation and/or local or multiple abscess formation.

Nineteen trainees who could perform OA without supervision but had variable experience in LA were the principal operators. Five consultants supervised them until they were considered safe to proceed on their own. Initially, a surgical registrar would assist or be supervised by a consultant, until considered safe to perform this procedure. The assisting consultant made this decision based on observation during LA, in which the trainee safely and independently successfully performed an LA. The operative approach was decided on by the surgeon on call.

Surgical technique

Three 5 mm bladeless Versaports™ from Medtronic® were used. One port for the camera, using a 30° telescope, was inserted through a supra-umbilical incision via an open method; the two remaining ports were inserted in the left lower quadrant and supra-pubically, respectively. After the appendix was visualised, which often required some adhesiolysis of small bowel adhesions and mobilising of the caecum, the meso-appendix was cauterised with a mono-polar hook diathermy. The appendix was then divided between 2 endo-loops and removed through the umbilical port site within either a finger of a glove, an Endo Catch, or directly through the port if a 10 mm umbilical port was used. The umbilical incision was then washed with Hibitane before it was closed using a 2-0 Vicryl suture (Ethicon, Somerville, NJ) for the sheath and 4-0 Vicryl sub-cuticular for the skin. In all LA, extensive peritoneal lavage was incorporated, using warm saline until the drainage effluent was clear. The abdominal wall was closed in 2 layers using 2-0 Vicryl sutures.

OAs were performed via a transverse Lanz incision in the majority of cases; infrequently, a lower midline incision was performed by the surgeon on call.

All patients received ampicillin, gentamycin and metronidazole for 5 days postoperatively. The need for continued or new antimicrobial therapy was based on clinical and ultrasound parameters. Easily accessible intra-abdominal abscesses were drained by an interventional radiologist under ultrasound guidance; if not, a relook laparotomy was considered.

Analgesia was given according to a strict protocol. Patients were discharged as soon as both oral intake and physical activity had recovered sufficiently and after five days of intravenous antibiotics had been completed. Postoperative complications were recorded both during hospitalisation and at follow-up until 30 days.

Primary endpoints were the rates of surgical site infection (SSI) or intra-abdominal abscess formation (IAA) until 30 days postoperative. The definition of surgical infection of the American College of Surgeons National Surgical Quality Improvement Program (ACS-NSQIP) was applied. Superficial SSI applied to infections involving only the skin or subcutaneous tissue at the incision site; deep SSI to infections involving deep soft tissues (e.g., facial and muscle layers); and organ-space SSI to infections involving any part of the anatomy that was opened or manipulated during an operation.[16] The definition of stump leakage included any clinical or radiologic evidence of a complication, for example faecal discharge of intestinal content through a drain, whether re-operation or any other intervention was required.

Results of surgeries performed by surgical trainees and consultants were retrospectively reviewed. A comparison was made between operative time and occurrence of complications during initial LA and subsequent ones. Four trainees were experienced with LA, having attended a laparoscopic cholecystectomy and advanced suturing techniques course and performed more than 10 LAs prior to the study period. In these cases, a consultant observed the first LA in theatre while not scrubbed. Of the remaining 15 trainees, nine had attended a similar laparoscopic course but were not capable of performing an unsupervised LA. Five consultants performed or supervised LA during the study period, two with less than a year's experience in this position but having performed more than 20 LAs and attended a similar laparoscopic course. The remaining consultants had more than 20 years' surgical experience each, which included a variety of more complex laparoscopic procedures.

Other variables compared were: preoperative waiting time (time from admission to theatre), experience of the operating surgeon (senior trainees: > 2 years in training position, attended a laparoscopic training course and performed > 10 LA; senior consultant: > 20 years in consultant position, attended a laparoscopic training course and performed advanced laparoscopic surgeries); length of operating time (time from skin incision to exit from theatre); incidence of conversion from LA to OA; recovery of bowel movement and initiation of oral intake; restoration of physical activity; length of postoperative hospital stay; and the incidence of adhesive bowel obstruction or incisional hernia.

Statistical analysis

Over the 4-year study period, all patients receiving an appendectomy for CA were either included in the OA or LA groups according to the procedure undertaken for each patient, decided by the surgeon on call (simple random sampling for a retrospective study). The chi-square test and the Fisher's exact test were used for comparison of categorical variables. Continuous variables were compared using a t-test when normally distributed. In all tests, $p < 0.05$ was regarded as significant.

Results

One hundred and forty-one out of 155 children who had an appendectomy for a CA were included in the study. Fourteen children were excluded, two because they were outside the specified age range (aged 2.5 and 3 years respectively), 10 had insufficient clinical data, and two were unstable, requiring PICU admission.

One hundred and forty-one patients underwent appendicectomy, 90 OA and 51 LA. Lanz incisions were performed in 86 OA and four midline incisions. Eight had a LA converted to OA (15.7%), one by a senior consultant and seven performed by trainees not supervised by a

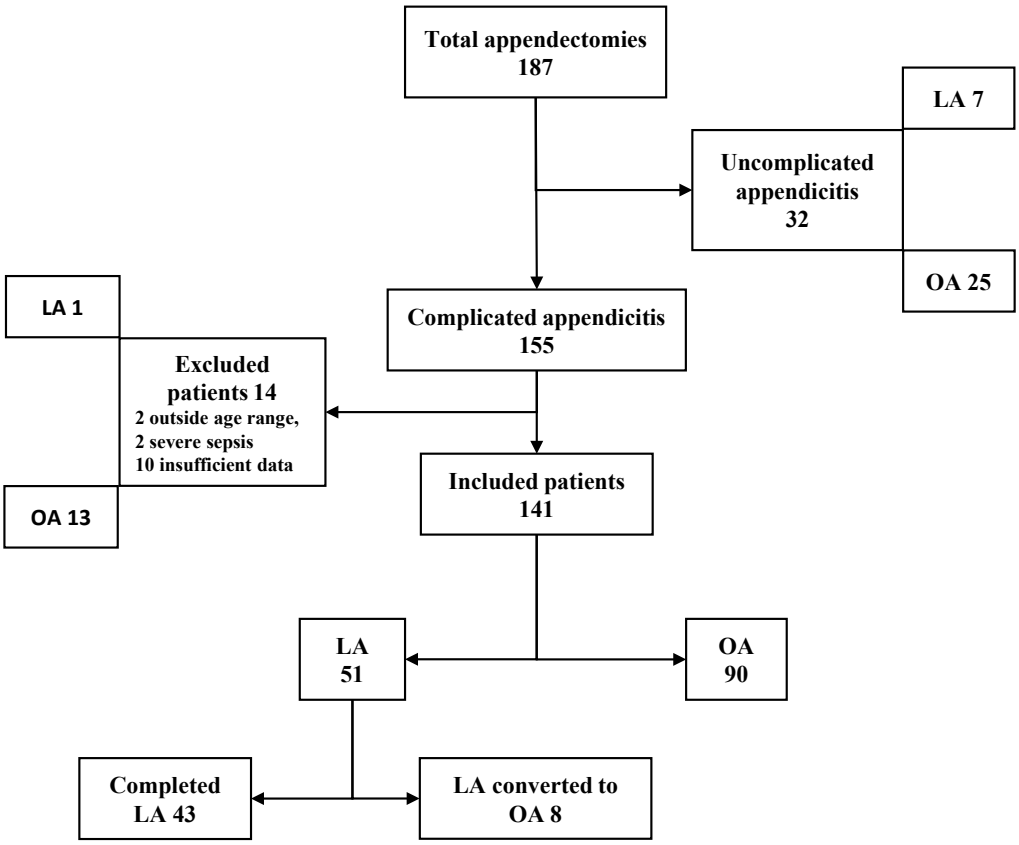

Figure 1: Consort diagram of all patients with appendicitis during study period

consultant. Reasons for conversion were: four technically too challenging, two poor assistance, three equipment failure and one necrotic caecum. All were followed for 30 days postoperatively.

Patients and disease characteristics, age, gender and weight for age had an equal distribution between the two groups (Table I). There was no statistically significant difference between LA (11; 25.6%) and OA (23; 25.6%) regarding SSI, incisional or organ space SSI (Table II), (p = 0.159). A single case of stump leakage was recorded in an LA that had to be converted to OA. This complication was managed conservatively with spontaneous closure 4 weeks post-surgery.

Incidence of bowel obstruction was two (2.2%) in OA and two (3.9%) in the LA group (p = 0.29). No intraoperative complications or mortality occurred in either group (Table III).

One patient, in the LA group, had a suction drain through a port site left in a large abscess cavity.

Four patients were known to be HIV-positive: three in the OA and one in the LA group. Two in the OA group developed an IAA. Two patients had previous surgery, one for the repair of a tetralogy of Fallot and the other for excision of a vitelline duct anomaly; both had an OA.

Eleven in the OA group developed an IAA. Five pigtails were placed in four patients by an interventional radiologist to drain the IAA. Five patients required a relook laparotomy, and the other two resolved without intervention. Nine patients developed IAA in the LA group (one performed by a senior consultant, three by trainees assisted by a consultant and five by trainees without consultant supervision). Pigtail drainage was successful in two patients. Four patients required relook surgery to drain the IAA, one of which was done laparoscopically. In all patients of both groups, an infected wound was opened to obtain full drainage followed by saline lavage and, if required, an Intracite® gel dressing (Smith & Nephew, TM).

In the LA group, the appendiceal stump was either suture ligated intra-corporally, in four cases (9.3%), or tied off with an endo-loop. All OAs had the appendiceal stump suture ligated.

Four senior trainees performed five LAs without consultant supervision. Ten junior trainees assisted a consultant 14 times during LA, followed by 10 LAs where the consultant assisted the junior trainee. Subsequently, the 10 junior trainees performed 22 LAs without consultant supervision.

Duration of surgery differed significantly between LA (98.1 min; IQR 40) and OA (60.64 min; IQR 33.75; p = 0.029) (Table III).

The mean duration of surgery LA for surgical trainees was 110.35 minutes (SD 43.19), and for consultants 93.87 min, (SD 32.12; p = 0.497; 95% CI 10.26–21.48).

Postoperative recovery of food intake did not differ significantly between the two groups. Nine patients in the OA group and six patients in the LA group required a change of their antimicrobial therapy.

Seven patients (7.8%) in the OA and five (9.8%) in the LA group required an incisional hernia repair.

Discussion

Complicated appendicitis, defined as a gangrenous/necrotic, perforated appendicitis with local or diffuse abscess formation, is associated with an increased morbidity rate. Within the literature, a wide range of post-appendectomy infective complications are reported, this is further influenced by patient age, disease severity (CA), delayed presentation,

Table I: Patient demographics by type of surgery

Characteristics	LA *n* = 43		OA *n* = 90		LA to OA *n* = 8	
	Mean	IQR	Mean	IQR	Mean	IQR
Age years	8.9	3	7.7	4	10.6	2.25
Symptom duration (days)	3.2	1	2.4	2	4.3	2
In hospital waiting time (days)	19.95	12.25	18.67	15	17.63	10.75
Gender ratio (M:F)	2:1		3:1		3:1	
Comorbidities (n)	1		3		0	
Prior surgery (n)	0		2		0	

Table II: Postoperative complications related to type of surgery

Complication	LA *n* = 43		OA *n* = 90		LA to OA *n* = 8		*p*-value
	n	%	*n*	%	*n*	%	
Incisional hernia	4	9.3	7	7.8	1	12.5	0.8
Stump leakage	0	0	0	0	1	12.5	
Bowel obstruction*	2	4.7	2	2.2	0	0	0.39
SSI	11	25.6	23	25.6	2	25	
Local	5	11.6	17	18.9	2	25	0.48
Intra-abdominal	9	20.9	11	12.2	0	0	1.46

*Required adhesiolysis 2

Table III: Clinical outcomes related to type of surgery

Outcome variables	LA		OA		LA to OA		*p*-value
	Mean	SD	Mean	SD	Mean	SD	
Operative time (mins)	104.5	33.63	60.64	24.32	91.63	49.71	0.0001
Days to full feeds	2.82	0.93	3.18	1.11	4.25	1.41	0.065
Antimicrobial duration (days)	5.03	2.07	5.09	2.48	5.31	1.39	0.71
Hospital stay (days)	5.98	2.36	6.54	3.63	9.75	4.80	0.45
	n	%	*n*	%	*n*	%	
Abscess	9	20.9	11	12.2	0	0	0.146
Interventional radiology	2	4.65	5	5.56	0	0	0.594
Relook laparotomy	6	13.95	6	6.67	0	0	0.147
Mortality	0	0	0	0	0	0	

surgical approach and surgical expertise.[3-6,8,17,18] Our study compared surgical approach during appendicectomy to postoperative complication rates. We could not confirm a higher incidence of IAA formation, which has been reported in other retrospective studies repeatedly.[2,10,11] It would seem plausible that LA for perforated appendicitis should result in a decreased incidence of IAA since the visualisation of the abdominal cavity is superior and a more thorough washout of all 4 quadrants can be performed. The varied method of appendix removal, which was the operating surgeon's choice could have affected the rate of IAA. No significant difference in the rate of organ/space SSI was found between the two study groups, and the incidence of re-operation and need for pigtail for abscess drainage was consistent with recent retrospective studies.[2-4] CA accounted for 82.9% of the patients referred to our tertiary specialist centre. This correlates to literature stating that paediatric hospitals admit double the cases with CA compared to district hospitals.[5,17,18] A paediatric meta-analysis found increased IAA associated with LA for CA.[2] Other reports suggest that disease severity rather than operative approach is associated with an increase in IAA that is in keeping with the high South African incidence of advanced disease and perforation.[2,6,10,11,18]

The surgical approach to appendectomy in our paediatric division changed to LA from August 2012, due to rotating general surgeon's introduction into the paediatric rotation, improved availability of laparoscopic instruments and surgical trainees' increased requirement for laparoscopic training. This is in keeping with global trends where LA has gained popularity in adult and paediatric surgical practice.[17-20]

Operative time was significantly longer between LA and OA but compares favourably for LA between surgical trainees and consultants for CA. Operative time is comparable with other paediatric LA for CA studies.[6] The conversion rate is similar to recent literature and correlates with the high incidence of CA.[13,14] The learning curve, defined as the number of supervised LAs a trainee needs to

perform independently and safely, has been reported to range from 2.5 to 30 cases.[13-15,20] Indicating that surgical trainees acquire the skill relatively easily. Most of our patients had severe inflammation due to CA; this affected operative time as seen by the similar operative time between trainees and consultants.

With the comparable intra- and postoperative complications in the LA and OA groups, we propose LA as a feasible teaching model for training surgical registrars in laparoscopic surgery. Surgical trainees acquire the skill over a short period of time and after a steep learning curve.[13-15] This corresponds to recent series indicating that paediatric surgeons had a higher probability to approach CA with an LA with less prevalent complications.[7]

Intra-abdominal loop or suture ligation of the appendiceal stump was successfully done in all LA patients and there was no need for staplers. One patient, who had to be converted, developed a stump fistula which closed spontaneously 4 weeks after insertion of a drain. This compares to reported closure rates without surgical intervention of 90% within one month following resolution of sepsis.[21] No mortality occurred in this group.

No comparison could be made regarding the requirements of analgesia and antibiotics, but the strict postoperative protocol followed for all patients in this study may explain the similar hospitalisation periods for LA and OA. This is particularly true in CA, where antimicrobial protocols dictate the duration of intravenous therapy, which is often the main determinant of hospital stay.[4,17,18,22]

This review has the limitation of being retrospective with no randomisation of the treatment options. Additional limitations were: appendix retrieval through a bag was variable and could have affected the SSI; data on important endpoints cosmesis; and cost considerations were not measured.

Conclusion

Despite being a retrospective observational study using a relatively small patient cohort from an academic centre with a dedicated paediatric surgical service,[3,17] we have demonstrated that LA for CA is feasible as a training operation in a well supervised programme despite the heterogeneity of surgical experience and training of the surgeons involved. LA has comparable outcomes to OA except for longer operating time. The different levels of trainees' expertise in laparoscopic surgery and OA merits more critical analysis.

Conflict of interest

The authors declare no conflict of interest.

Funding source

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Ethical approval

Ethical approval from HREC of University of Stellenbosch, Tygerberg hospital local board was obtained (Ref: S16/06/103).

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