Original Article

Prospective Study of Laparoscopic Management of Appendicitis during the COVID Pandemic in a Single Paediatric Centre

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Abstract

Background: The coronavirus (COVID-19) pandemic affected the presentation of many conditions. This study analyses and describes the impact of the COVID-19 pandemic on the management of appendicitis in children and the role of laparoscopy. **Materials and Methods:** We performed a prospective (during the pandemic) and retrospective (historic control) review of the management of appendicitis in a tertiary paediatric surgical unit. Preoperative data, operative findings and patient outcomes were compared between groups to identify differences between the study periods and to identify any factors predictive of outcomes. **Results:** Sixty-two patients were identified in the pre-pandemic cohort, 72 in the pandemic cohort. There was no significant difference in patient demographics, length of admission or time between admission and surgery between groups. There was however a significantly longer time to presentation to hospital in the pandemic group. Clinical outcomes were comparable between the two groups, with no difference in the presence of surgical complications or histologically advanced appendicitis between the two groups. Laparoscopic surgery was safely used to manage appendicitis in the pandemic cohort through utilisation of a COVID-19 pathway that included guidance on testing, and use of personal protective equipment (PPE). Conservative management in the pandemic cohort was reserved for patients with appendicitis with the presence of mass formation. **Conclusion:** Despite a delayed presentation to hospital, there was no rise in the incidence of complicated appendicitis, complications of surgery or length of stay during the COVID-19 pandemic. Laparoscopic appendicectomy was also shown to be a safe and effective standard for the management of appendicitis during the pandemic. **Level of Evidence:** III, treatment.

Keywords: Appendectomy, appendicitis, COVID-19, laparoscopy

Introduction

Appendicitis presents early with uncomplicated/simple appendicitis with minimal morbidity, or late with severe complications and morbidity, and rarely mortality. It is one of the most common emergency conditions managed by paediatric surgeons, with a peak incidence between 10 and 20 years of age. It is known that late presentation increases complexity and morbidity, especially in children.[1,2] Operative intervention is the mainstay of management with the current evidence and historic precedent. Minimally invasive surgery has been the gold standard of management for some time in centres with experience of laparoscopic management.[1,3] Open surgery is associated with higher complication rates (wound infection and adhesions) longer hospital stay and higher levels of reported post-operative pain.[1]

The severe acute respiratory syndrome coronavirus 2 coronavirus (COVID-19) pandemic affected both access to, and approach in the management of many conditions. In a key report by the Royal College of Paediatrics and Child Health on the impact of COVID-19 on children's elective surgery, by July 2020, over 30,000 children in England had procedures delayed due the pandemic. Furthermore, early guidance and response letters issued from United Kingdom Royal Colleges and surgical associations warned of the potentially crippling effects of the emerging COVID-19 pandemic on both elective and emergency treatment capacities of most UK healthcare units.[4] Guidance was also given around the risk of spread of

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Received: 31-12-2021 **Revised:** 24-02-2022 **Accepted:** 16-03-2022 **Available Online:** 15-12-2022

Access this article online

Quick Response Code:

Website: www.afrjpaedsurg.org

DOI: 10.4103/ajps.ajps_181_21

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How to cite this article: Dass D, Hotonu S, McHoney M, Munro F. Prospective study of laparoscopic management of appendicitis during the COVID pandemic in a single paediatric centre. Afr J Paediatr Surg 2023;20:40-5.

COVID-19 specifically by aerosol-generating procedures, of which minimally invasive surgery was a point of contention.[4,5]

The Royal College of Surgeons England suggested avoiding aerosol-generating procedures such as endoscopy and laparoscopy, to reduce the risk of COVID-19 infection of theatre staff.[6,7] It was also recommended that where open operations are feasible and safe, or non-operative treatments available, these should be used to avoid surgery for all conditions, including appendicitis, if considered an acceptable alternative treatment option. Certainly, the use of non-operative management of appendicitis is widely reported, especially in cases of uncomplicated appendicitis. This is however not without risk, with recurrent appendicitis reported in up to 15% of patients within 1 year.[8-10]

There were early studies reporting the absence of the COVID-19 virus in the peritoneal fluid of actively infected patients.[11] Conversely, these were soon followed by reports which identified the virus in peritoneal fluid of confirmed active cases.[12] Aerosol contamination of surgical smoke emitted during diathermy has been confirmed in cases of Hepatitis B-positive patients.[5]

Minimal access surgery has been safely practiced in our centre for a wide range of paediatric and neonatal conditions. With the support of our theatre and anaesthetic colleagues, our surgical department was able to rapidly develop a local protocol to facilitate safe theatre practice during the COVID-19 pandemic [Figure 1], which was implemented by April 2020. We report our experience of laparoscopic management of appendicitis during the pandemic, and compare this to a historic cohort over a comparative pre-pandemic period.

Our primary outcome was to compare the percentage of patients presenting with complicated appendicitis between periods. Second, we aimed to define the outcome of paediatric appendicitis during the COVID-19 pandemic to the historical cohort, to define the factors that might be associated with outcome in our population, and to outline the role of operative and laparoscopic surgery during the pandemic.

Materials and Methods

Inclusion criteria

We participated in prospective multicentre observational cohort study of children aged <16 years at the time of hospital admission diagnosed with and treated for acute appendicitis in the UK and Ireland between 1 April 2020 and 31 May 2020.[13] For this COVID-19 period, the data required by the multicentre study was prospectively recorded using the study proforma and data recording Microsoft Excel database. We extended the prospective data collection over a longer period of the pandemic (up to 31 August 2020). We compared them to a historic cohort over the same period in the year 2019 as a historical control (pre-COVID-19 group). The same data were retrospectively retrieved from the historic patients. This data were retrieved from the clinical notes from the electronic notes and our surgical audit database. The study was registered with our local quality improvement team and approved by the Research and Ethics committee. As this was a service evaluation/clinical outcome study no formal patient consent was required.

Once a diagnosis was made, patients were commenced on a standardised intravenous antibiotic regimen of Cefuroxime and Metronidazole. All patients in the COVID-19 group underwent testing upon admission for COVID-19 by polymerase chain reaction (PCR). This was performed for anticipation of admission and surgery, but also in view of emerging evidence of Paediatric Multisystem Inflammatory Syndrome.[14]

Data collection and outcome measures

Data recorded included patient presenting features, the treatment strategy for acute appendicitis, defined as surgical or non-operative, and postoperative outcome. Outcomes related to patient management included the number and proportion of cases performed open and laparoscopically, use of diagnostic imaging, the severity of disease and variation in patient management over the two time periods. Other clinical outcomes were failure rate of non-operative treatment (defined as appendicectomy within initial hospital inpatient episode in a case in whom the initial treatment strategy was non-operative), surgical complications, length of hospital stay and mortality.

We defined three pathway steps (measured in days) in our management of patients. Time to diagnosis was defined as the time from admission to hospital until the diagnosis of appendicitis was made and the appropriate management embarked upon. Delay to theatre was the time diagnosis of appendicitis and decision to operate to the time patient was taken to theatre for surgical management. Time to operation was the time from admission until the patient was taken to theatre.

At operation, the surgical staging was defined as complicated if there were signs of perforation, pus, necrosis or mass formation. It was defined as simple otherwise. The histological features on pathological examination were also recorded.

Statistical analysis

Statistical analysis was performed using SPSS Statistics for Windows (IBM Corporation 2015, version 23.0, Armonk, NY, USA). Results are described using percentages, median + interquartile range. Continuous variables were analysed using *t*-test and Mann–Whitney *U*-test for non-normally distributed data. Categorical variables were analysed using Pearson's Chi-squared (X^2) test and Fisher's exact test. Multivariable logistic regression was performed to investigate the relationship between variables and outcome measures. Confounding variables were period of study, COVID-19 status, duration of symptoms, time to surgery, age, C-reactive protein (CRP) level, WCC and highest pre-operative temperature recorded. A $P < 0.05$ was considered significant.

Results

Patient demographics

There were 62 patients in the pre-COVID-19 era and 72 patients in the COVID-19 period managed for acute appendicitis. The demographics of the population and presentation characteristics are shown in Table 1. Of note, there was no statistical difference in the patient demographics, white cell count, CRP or highest temperature at admission between groups. However, there was a significantly longer duration of symptoms before presenting to the hospital during the COVID-19 pandemic. All patients tested negative for COVID-19 in the COVID-19 era group.

Patient management

Table 2 displays the timeline in both groups of patients. Of note patients in the COVID-19 period had a longer wait between having a diagnosis of appendicitis and getting to theatre; this however did not reach statistical significance. In the pre-COVID-19 period 85% of patients had their surgery on the day of diagnosis, whereas this figure was 75% in the COVID-19 group. There was no significant difference in any of the pathway timelines.

Ultrasound scanning (USS) was performed to either establish or confirm the diagnosis more frequently during the COVID-19 period (55/72; 77%) than the pre-COVID-19 group (32/62; 51%; $P = 0.001$). The one computed tomography scan performed in this study period (pre-COVID-19 group) was performed by a local general hospital before referral to our tertiary paediatric centre.

There were no indications for treating appendicitis conservatively in the pre-COVID-19 cohort. Four patients commenced non-operative management in the COVID-19 group following clinical and USS diagnosis of appendix mass. Two patients were managed successfully however two patients experienced progression of symptoms necessitating escalation to surgery; both were carried out successfully laparoscopically.

In the pre-COVID-19 group, open appendicectomy was carried out on two occasions, one as part of a laparotomy

COVID 19 PANDEMIC THEATRE PATHWAY

RED Pathway: COVID Positive or Highly Suspected	GREEN Pathway: COVID Negative (PCR Confirmed)
- Team briefing: clinical and PPE plan - Clinical preparation as per COVID checklist	- Team briefing: clinical and PPE plan - Clinical preparation as per COVID checklist
- Done airborne PPE (Anaesthetist and ODP with buddy checklist)	- Wear FRSM/ eye protection/ gloves/ apron (anaesthetist, OPD, 3rd assistant)
One parent and HCP can stay with child for induction of anaesthesia	One parent and HCP can stay with child for induction of anaesthesia
Induction in anaesthetic room - Parents and HCP leave and door locked - 3rd assistant in theatre for immediate help	Induction in anaesthetic room - Parents and HCP leave and door locked - 3rd assistant in theatre for immediate help
For sterile anaesthetic procedure (CVC/ epidural) anaesthetist wears sterile gown and sterile gloves over airborne PPE	For sterile anaesthetic procedure (CVC/ epidural) anaesthetist wears sterile gown and sterile gloves in addition to fluid resistant PPE
- Patient can be transferred into theatre when clinically ready (no need to wait for air changes) - Surgery and scrub team in fluid resistant PPE unless surgery is AGP - Ventilator circuit must not be broken between tube and HME filter	Move patient into theatre when clinically ready Scrub team in fluid resistant PPE
- WHO checklist - Commence surgery/procedure	- WHO checklist - Commence surgery/procedure
- End of procedure - All surgical and scrub staff leave theatre - Proceed to extubation (airborne precautions)	- End of procedure - All surgical and scrub staff leave theatre - Proceed to extubation (fluid resistance precautions)
- Patient recover in theatre by anaesthetic team - 3rd assistant available in prep room if needed for immediate assistance - No additional staff to enter or exit theatre	- Patient recovery in recovery department - No need to wait 20 minutes - Recovery team in fluid resistant PPE
After 20 minutes, patient may be collected from theatre by ward staff (if ready) to return directly to ward	Anaesthetic room, theatre and equipment decontaminated as per hospital policy
PPE removed in sluice room and disposed	Disposal of fluid resistant PPE as per hospital policy
Theatre and equipment decontaminated as per hospital policy	

Figure 1: Departmental protocol for theatre cases performed during the COVID-19 pandemic

Table 1: Demographic and presenting data between groups

	Pre-COVID-19 group (*n*=62)	COVID-19 group (*n*=72)	*P*
Age (years)	10.0 (7.0-11.0)	11.0 (7.0-12.0)	0.203
Sex female	22	23	0.667
	40	48	
Duration of symptoms (h)	24.0 (20.0-48.0)	48.0 (24.0-72.0)	0.015
Highest temperature (°C)	37.9 (37.4-38.3)	37.5 (36.8-38.2)	0.102
White cell count	14.3 (11.4-17.8)	14.6 (11.2-17.3)	0.564
Neutrophil count	12.0 (8.9-14.5)	11.0 (8.6-14.0)	0.285
C-reactive protein	43.0 (16.0-92.0)	65.0 (12.0-103.5)	0.479

Data is represented as median and interquartile range

Table 2: Outcome data between patients in groups

	Pre-COVID-19 group (*n*=62)	COVID-19 group (*n*=72)	*P*
Admission to diagnosis	0 (0-1)	0 (0-1)	0.883
Admission to surgery	1 (0-1)	1 (0-1)	0.173
Diagnosis to surgery	0 (0-0)	0 (0-3)	0.111
Hospital stay	4 (3-5)	3 (2-6)	0.525

Data are all in completed days and are represented as median and interquartile range

Table 3: Histological diagnosis in the two groups

	Pre-COVID-19 (*n*=62)	COVID-19 (*n*=70)
Early (inflamed) appendicitis	34	45
Advanced (perforated) appendicitis	25	25
Other pathology	3	0
Perforation rate (%)	40.30	35.70

in the grossly septic child with peritonitis, the second due to conversion of laparoscopic to open surgery with initial concerns of necrosed serosa of adjacent bowel. In the COVID-19 group, one patient underwent open appendicectomy, after conversion from laparoscopy following difficulty establishing the anatomy safely. All others were performed laparoscopically.

Outcome measures

The surgical staging of appendicitis at operation is shown in Figure 2. There was significantly more complex appendicitis in the pre-COVID-19 group ($P = 0.037$).

Three patients were found not to have appendicitis at surgery, two were macroscopically normal, the third was found to have omental torsion. One patient with appendicitis in the COVID-19 group was later confirmed to have carcinoid at the tip of the appendix.

Table 3 demonstrates histologically diagnosis of the resected specimens; all patients were managed operatively in the pre-COVID-19 cohort, and 70 patients (including two failures of conservative management) in the COVID-19 cohort.

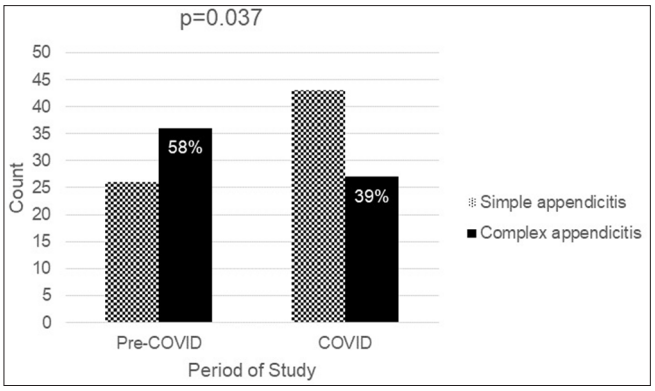


Figure 2: Comparison of the intra-operative staging of the severity of appendicitis between the pre-COVID-19 and COVID-19 cohorts. Statistically significant increased incidence of complex appendicitis was observed in the pre-COVID-19 cohort ($P = 0.037$)

Overall, there was no significant difference in either time to discharge from the operation or overall length of stay between groups [Table 2]. There was no mortality in either group.

Discussion

Being the most common surgical emergency in paediatrics, management and outcome of appendicitis is a valuable marker of the effect of the COVID-19 pandemic on services. The possible delays in presentation, availability of equipment and PPE, options for non-operative management and avoidance of laparoscopic intervention during the pandemic were all variables which could have led to a difference in outcome to patients.[13,15] We demonstrate that with adherence to best surgical principles, with adaptation to the emergence of the COVID-19 pandemic, allowed patients to continue to have access to gold-standard care without affecting morbidity or mortality.

Our results demonstrated no significant differences in the patient demographic between study periods. This suggests that COVID-19 did not affect the short-term epidemiology of appendicitis. However, there was a significantly delayed presentation in the COVID-19 period, which amounted to almost 2 days. Despite this, measured indices of inflammation were not different between groups. This 2 days delay in the presentation did not to correlate with the markers of inflammation. The delay in presentation could be due to patients/parents/carers not wanting to travel or access the hospital during the peak of the pandemic, with its associated risks. This delay in the presentation during the pandemic has been well recognised elsewhere.[15-18]

Increased use of ultrasonography is noteworthy in the COVID-19 period. This may indicate attempts to maximise diagnostic accuracy and minimise unwarranted intervention during the risky period of the pandemic. Despite the higher use of ultrasound, the negative appendicectomy rate was similar in both groups, suggesting good clinical diagnostic acumen during both periods. Despite the increased use of imaging,

the time from admission to the diagnosis of appendicitis was unchanged. We do note, however, that there was a small delay to the delivery of operative treatment during the COVID-19 period once a diagnosis was confirmed compared with the pre-COVID-19 group, however this was not significant. Despite the combined delay, the proportion of early and advanced appendicitis was broadly equivocal between groups. The possible 2 days of delay did not lead to a higher complication rate in the COVID-19 period. In fact, the rate of complex appendicitis at surgery was lower in the COVID-19 group. We could not find an explanation for this unexpected inverse relationship. Overall, the perforation rates reported in our study population (38%) conform to previously reported perforation rates by other authors.[19,20]

Rapid COVID-19 testing allowed for testing of almost all patients requiring surgery. Wherever deemed safe and appropriate, the operative intervention was delayed until COVID-19 PCR results were made available. With specific regard to laparoscopic surgery, it was agreed that the pneumoperitoneum should be evacuated through an auxiliary laparoscopic port tap via attached tubing and Clear-Guard™ air filter, to minimise any theoretical aerosolisation. No patients (or staff attending to them) developed COVID-19 during the study period.

Non-operative management is also proposed for the management of appendicitis in children and was proposed during the pandemic. Papers have reported on the outcome for non-operatively managed patients during the pandemic.[18,21] We are happy to report a successful maintenance of both a surgical management pathway, while also maintaining a minimally invasive approach. Of note, we also had one case of a carcinoid in and inflamed appendix diagnosed at histology. This prompted further assessment and staging, with a successful outcome, and no need for further intervention. Although not common, with a reported incidence of 0.5% of all appendectomies, missing this diagnosis with non-operative management can lead to a poor outcome if progression occurs.[22]

Conclusion

Despite a delayed presentation and a slightly longer delay between admission and surgical management during the pandemic, there was no rise in the incidence of complicated appendicitis, complications of surgery or length of stay during our study. Prompt clinical diagnosis, resuscitation, antibiotics and surgical management allows for a good outcome in appendicitis. Laparoscopic appendicectomy was also shown to be a safe and effective standard for the management of appendicitis during the pandemic.

Acknowledgements

Mr. Hetal Patel, Paediatric Surgery Registrar, for his assistance in data collection

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

References

1. Aziz O, Athanasiou T, Tekkis PP, Purkayastha S, Haddow J, Malinovski V, *et al.* Laparoscopic versus open appendectomy in children: A meta-analysis. Ann Surg 2006;243:17-27.
2. Markar SR, Blackburn S, Cobb R, Karthikesalingam A, Evans J, Kinross J, *et al.* Laparoscopic versus open appendectomy for complicated and uncomplicated appendicitis in children. J Gastrointest Surg 2012;16:1993-2004.
3. Wei HB, Huang JL, Zheng ZH, Wei B, Zheng F, Qiu WS, *et al.* Laparoscopic versus open appendectomy: A prospective randomized comparison. Surg Endosc 2010;24:266-9.
4. Updated Intercollegiate General Surgery Guidance on COVID-19 | ASGBI – Association of Surgeons of GB n.d. Available from: https://www.asgbi.org.uk/news/2020/mar/30/updated-intercollegiate-general-surgery-guidance-on-covid-19. [Last acessed on 2021 Aug 29].
5. Kwak HD, Kim SH, Seo YS, Song KJ. Detecting hepatitis B virus in surgical smoke emitted during laparoscopic surgery. Occup Environ Med 2016;73:857-63.
6. COVID-19: Good Practice for Surgeons and Surgical Teams – Royal College of Surgeons n.d. Available from: https://www.rcseng.ac.uk/standards-and-research/standards-and-guidance/good-practice-guides/coronavirus/covid-19-good-practice-for-surgeons-and-surgical-teams/. [Last accessed on 2021 Aug 29].
7. De Simone B, Chouillard E, Di Saverio S, Pagani L, Sartelli M, Biffl WL, *et al.* Emergency surgery during the COVID-19 pandemic: What you need to know for practice. Ann R Coll Surg Engl 2020;102:323-32.
8. Minneci PC, Hade EM, Lawrence AE, Sebastião YV, Saito JM, Mak GZ, *et al.* Association of nonoperative management using antibiotic therapy vs. laparoscopic appendectomy with treatment success and disability days in children with uncomplicated appendicitis. JAMA 2020;324:581-93.
9. Maita S, Andersson B, Svensson JF, Wester T. Nonoperative treatment for nonperforated appendicitis in children: A systematic review and meta-analysis. Pediatr Surg Int 2020;36:261-9.
10. Armstrong J, Merritt N, Jones S, Scott L, Bütter A. Non-operative management of early, acute appendicitis in children: Is it safe and effective? J Pediatr Surg 2014;49:782-5.
11. Ngaserin SH, Koh FH, Ong BC, Chew MH. COVID-19 not detected in peritoneal fluid: A case of laparoscopic appendicectomy for acute appendicitis in a COVID-19-infected patient. Langenbecks Arch Surg 2020;405:353-5.
12. Coccolini F, Tartaglia D, Puglisi A, Giordano C, Pistello M, Lodato M, *et al.* SARS-CoV-2 is present in peritoneal fluid in COVID-19 patients. Ann Surg 2020;272:e240-2.
13. Bethell GS, Rees CM, Sutcliffe JR, Hall NJ, CASCADE Study Collaborators. Management and early outcomes of children with appendicitis in the UK and Ireland during the COVID-19 pandemic: A survey of surgeons and observational study. BMJ Paediatr Open 2020;4:e000831.
14. Ahmed M, Advani S, Moreira A, Zoretic S, Martinez J, Chorath K, *et al.* Multisystem inflammatory syndrome in children: A systematic review. EClinicalMedicine 2020;26:100527.
15. Lee-Archer P, Blackall S, Campbell H, Boyd D, Patel B, McBride C. Increased incidence of complicated appendicitis during the COVID-19 pandemic. J Paediatr Child Health 2020;56:1313-4.
16. Lynn RM, Avis JL, Lenton S, Amin-Chowdhury Z, Ladhani SN. Delayed access to care and late presentations in children during the COVID-19 pandemic: A snapshot survey of 4075 paediatricians in the UK and Ireland. Arch Dis Child 2021;106:e8.
17. Cozzi G, Zanchi C, Giangreco M, Rabach I, Calligaris L, Giorgi R, *et al.* The impact of the COVID-19 lockdown in Italy on a paediatric emergency setting. Acta Paediatr 2020;109:2157-9.
18. Erlichman M, Zalut T, Schwartz S, Weiser G. The ongoing indirect effect of the COVID-19 pandemic on a pediatric emergency department. PLoS One 2021;16:e0251003.

19. Papandria D, Goldstein SD, Rhee D, Salazar JH, Arlikar J, Gorgy A, *et al.* Risk of perforation increases with delay in recognition and surgery for acute appendicitis. J Surg Res 2013;184:723-9.
20. Williams N, Bello M. Perforation rate relates to delayed presentation in childhood acute appendicitis. J R Coll Surg Edinb 1998;43:101-2.
21. Baral S, Chhetri RK, Thapa N. Comparison of acute appendicitis before and within lockdown period in COVID-19 era: A retrospective study from rural Nepal. PLoS One 2021;16:e0245137.
22. Gu Y, Wang N, Xu H. Carcinoid tumor of the appendix: A case report. Oncol Lett 2015;9:2401-3.