ASTR

ORIGINAL ARTICLE
pISSN 2288-6575 • eISSN 2288-6796
https://doi.org/10.4174/astr.2023.104.5.274
Annals of Surgical Treatment and Research

Impact of the COVID-19 pandemic on the outcomes of laparoscopic appendectomy for acute appendicitis

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Purpose: This retrospective study aimed to evaluate the impact of the coronavirus disease 2019 (COVID-19) pandemic on the time interval from symptom onset to surgery and on the operative outcomes of laparoscopic appendectomy for patients with acute appendicitis.
Methods: Between October 2018 and July 2021, laparoscopic appendectomy was performed in 502 patients with acute appendicitis admitted to Hallym University Chuncheon Sacred Heart Hospital in Chuncheon, Korea. We compared demographic data, serum levels of inflammatory markers, time to event of appendicitis, and operative outcomes between the pre-COVID-19 and post-COVID-19 pandemic groups.
Results: Laparoscopic appendectomy was performed in 271 patients in the pre-COVID-19 group and in 231 patients in the post-COVID-19 group. There were no differences in baseline characteristics, serum inflammatory marker levels, or the proportions of complicated appendicitis between the groups (25.1%, pre-COVID-19 vs. 31.6%, post-COVID-19; P = 0.106). The time intervals between symptom onset and hospital arrival (24.42 hours vs. 23.59 hours, P = 0.743) and between hospital arrival and the start of surgery (10.12 hours vs. 9.04 hours, P = 0.246) did not increase post-COVID-19. The overall 30-day postoperative complication rate did not differ significantly between the groups (9.6% vs. 10.8%, P = 0.650), and the severity of 30-day postoperative complications was also similar in both groups (P = 0.447).
Conclusion: This study demonstrates that hospitalization and surgeries were not delayed in patients with acute appendicitis and that the operative outcomes of laparoscopic appendectomy did not worsen despite the COVID-19 pandemic.
[Ann Surg Treat Res 2023;104(5):274-280]

Key Words: Appendicitis, Appendectomy, COVID-19, Laparoscopy

INTRODUCTION

The severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), causing the contagious coronavirus disease 2019 (COVID-19), was first identified in December 2019 in Wuhan, Hubei, China. Following its discovery and rapid spread, the World Health Organization declared COVID-19 a global pandemic on March 1, 2020 [1]. The containment and closure policies adopted by numerous nations have led to significant changes in people's daily lives, including their healthcare-seeking behavior. Patients would avoid hospitalization, fearing an in-hospital infection with COVID-19 [2]. Reduced healthcare utilization for acute conditions may result in increased disease severity [3].

These trends during the pandemic may have implications for outcomes in patients with appendicitis. An increase in

Received January 26, 2023, **Revised** April 7, 2023,
Accepted April 12, 2023

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pre-hospital delay for appendicitis was reported during the COVID-19 pandemic [4]. Delayed diagnosis or treatment of acute appendicitis can result in perforation, increased complication rates, and poorer clinical outcomes [5]. Several studies have reported an increase in the number of patients with complex acute appendicitis as well as longer times between symptom onset and hospitalization [5-7]. However, some studies found no significant increase in diagnoses of perforated appendicitis during the pandemic [8].

This study aimed to compare the characteristics and perioperative outcomes of patients who underwent appendectomy in Korea before and after the COVID-19 pandemic.

METHODS

Patients

This retrospective study drew its sample from the 703 patients who had undergone surgery for acute appendicitis at Hallym University Chuncheon Sacred Heart Hospital between October 2018 and July 2021. The study included patients who had undergone laparoscopic appendectomy for acute appendicitis and had been diagnosed using an abdominopelvic CT scan or abdominal ultrasound in the emergency department. Exclusion criteria were as follows: (1) patients who had been admitted via the outpatient department; (2) patients who had undergone open appendectomy or cecal resection; (3) patients who had undergone combined additional organ resection; (4) patients who had combined right colonic diverticulitis; and (5) patients who had missing data. After excluding 201 patients, 502 patients who had acute appendicitis were included in the analysis (Fig. 1).

Treatment details

Once acute appendicitis was diagnosed in the emergency department, surgery was planned as soon as possible. The first patient for whom COVID-19 was diagnosed in Chuncheon, Korea, was noted in February 2020. Preoperatively, COVID-19 PCR tests began in July 2020 and were mandatory from September 2020. Third-generation cephalosporins were administered to all the patients, and metronidazole was added when complicated appendicitis was suspected. Under general anesthesia, each patient was placed in the supine position. All laparoscopic appendectomies were conducted by 1 of 7 surgeons, each of whom had experience, having performed more than 200 such surgeries. Surgical techniques (single-port laparoscopic surgery [SPLS] or multiport laparoscopic surgery [MPLS]) and details of operative procedures (trocar placement, method of appendiceal artery ligation or appendiceal resection, and surgical drainage insertion) were decided based on the surgeon's preference. Postoperatively, antibiotics were continued for approximately 3 days. Dietary intake and the discharge plan were determined based on intraoperative findings indicating the severity of inflammation and the postoperative condition of the patient. The discharge criteria were as follows: no evidence of surgical site infection or other complications; a tolerable soft diet; and pain controlled by oral analgesia.

Outcomes measured

This study was approved by Institutional Review Board/Ethics Committee of Hallym University Chuncheon Sacred Heart Hospital (No. CHUNCHEON 2021-06-021) and was carried out in accordance with the Declaration of Helsinki. The requirement for obtaining written informed consent was waived due to the study's retrospective and observational design. Data were collected by reviewing electronic medical records and were registered using a newly developed case reporting form (CRF). The CRF for this study included baseline data (sex, age, body mass index [BMI], American Society of Anesthesiologists physical status [ASA PS] classification, history of previous abdominal surgery, complete blood count, and CRP level at admission), time to symptom onset, time to hospital arrival, and time to start surgery. Time to symptom onset was defined as the time when the patient first experienced abdominal pain or fever. Operative data included the type of appendicitis (uncomplicated or complicated), laparoscopic surgical technique (SPLS or MPLS), conversion to open surgery, operation time, 30-day postoperative complication and mortality rates, time to functional recovery and discharge, and readmission. Postoperative complications were stratified according to the modified Clavien-Dindo classification [9]. Complicated appendicitis was defined as a perforated and/or gangrenous

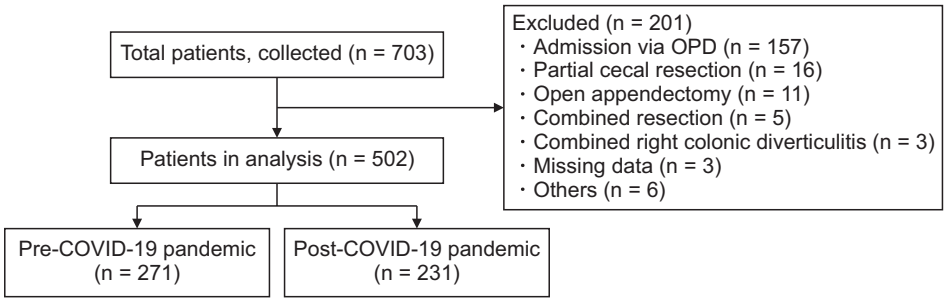

Fig. 1. Study flow. OPD, outpatient department; COVID-19, coronavirus disease 2019.

lesion with or without abnormal fluid collection or abscess formation [10]. Postoperative complications were defined before data collection. Wound complication was defined as purulent or serous discharge from the surgical wound. Intraperitoneal abscess was defined as abscess formation or abnormal fluid collection seen on abdominal CT or ultrasound images. Voiding difficulty was defined as voiding failure requiring the insertion of a Foley catheter. Prolonged ileus was defined as the absence of flatus passage with small bowel distension within 5 postoperative days.

Statistical analyses

We compared the results of laparoscopic appendectomy for acute appendicitis obtained before and after the day (February 22, 2020) the first patient with COVID-19 was reported in Chuncheon, Korea (pre-COVID-19 pandemic *vs.* post-COVID-19 pandemic groups). Baseline data and operative outcomes were compared using the Student t-test for continuous variables and the chi-square test or Fisher exact test for nominal variables. A P-value of <0.05 was considered statistically significant. All statistical analyses were performed using IBM SPSS Statistics ver. 22.0 for Windows (IBM Corp.).

RESULTS

Baseline characteristics

The total study sample of 502 patients (293 male and 209 female) had a mean age of 39.0 years (range, 4–89 years) and a mean BMI of 23.54 kg/m^2 (range, 13.78–38.20 kg/m^2). The ASA PS grade was I in 360 patients (71.7%), II in 93 patients (18.5%), III in 48 patients (9.6%), and IV in 1 patient (0.2%). Laparoscopic appendectomies were performed in 271 patients before the COVID-19 pandemic and in 231 patients after the COVID-19 pandemic. All the patients in the post-COVID-19 group had negative PCR results. Table 1 shows the baseline characteristics of the pre- and post-COVID-19 pandemic groups. There were no significant differences in terms of sex, age, BMI, ASA PS grade, or history of previous abdominal surgery. Inflammatory markers, such as WBC count, neutrophil count, CRP level, neutrophil-to-lymphocyte ratio, and platelet-to-lymphocyte ratio at admission, were not significantly different between groups. The proportion of complicated appendicitis was not significantly different between groups (25.1%, pre-COVID-19 *vs.* 31.6%, post-COVID-19; P = 0.106). The durations between symptom onset and hospital arrival (24.42 hours *vs.* 23.59 hours, P = 0.743) and between hospital arrival and the start of surgery were similar in both groups (10.12 hours *vs.* 9.04 hours, P = 0.246). Fig. 2 shows the number of laparoscopic appendectomies performed per month. The number of operations varied greatly from month to month.

Operative outcomes

SPLS was more frequently performed in the pre-COVID-19 pandemic group than in the post-COVID-19 pandemic group

Table 1. Baseline characteristics

Characteristic	Group A Pre-COVID-19 pandemic (n = 271)	Group B Post-COVID-19 pandemic (n = 231)	P-value
Age (yr)	37.67 (4–84)	40.59 (6–89)	0.115
Male sex	155 (57.2)	138 (59.7)	0.564
Body mass index (kg/m^2)	23.33 (14.83–34.70)	23.78 (13.78–38.20)	0.200
ASA PS classification			0.100
I/II	250 (92.3)	203 (87.9)	
III/IV	21 (7.7)	28 (12.1)	
Previous abdominal surgery	26 (9.6)	21 (9.4)	0.847
WBC count (×10^9/L)	12.63 (1.99–32.13)	12.99 (3.99–27.26)	0.331
Neutrophil count (×10^9/L)	10.10 (1.40–28.70)	10.60 (3.10–25.20)	0.173
Hemoglobin (g/dL)	13.91 (8.80–18.40)	14.16 (8.70–18.70)	0.094
CRP (mg/L)	32.59 (0.60–341.80)	41.73 (4.00–357.60)	0.081
NLR	8.01 (0.64–56.00)	9.08 (1.38–42.00)	0.080
PLR	182.65 (38.93–758.00)	186.76 (61.00–887.50)	0.667
Type of appendicitis			0.106
Uncomplicated	203 (74.9)	158 (68.4)	
Complicated	68 (25.1)	73 (31.6)	
Duration between symptom onset and hospital arrival (hr)	24.42 (1.00–168.00)	23.59 (0.57–240.00)	0.743
Duration between hospital arrival and operation start (hr)	10.12 (1.72–151.37)	9.04 (1.30–35.00)	0.246

Values are presented as mean (range) or number (%).
ASA, American Society of Anesthesiologists; PS, physical status; NLR, neutrophil-to-lymphocyte ratio; PLR, platelet-to-lymphocyte ratio.

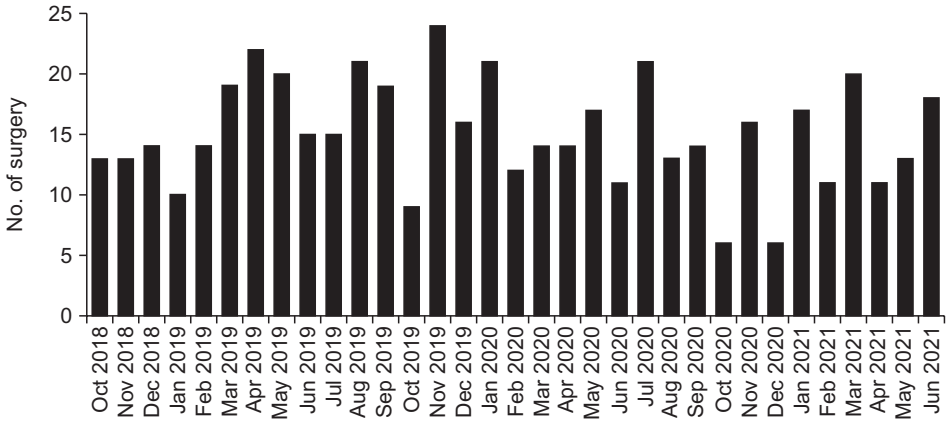

Fig. 2. Number of laparoscopic appendectomies performed per month.

Table 2. Operative outcomes

Variable	Group A Pre-COVID-19 pandemic (n = 271)	Group B Post-COVID-19 pandemic (n = 231)	P-value
Operation			<0.001
SPLS	135 (49.8)	46 (19.9)	
MPLS	136 (50.2)	185 (80.1)	
Conversion to open surgery	0 (0)	0 (0)	
Operation time (min)	36.23 (15–165)	31.62 (15–140)	0.001
30-Day postoperative complication			0.650
Overall	26 (9.6)	25 (10.8)	
30-Day postoperative complication			0.447
Grade 1	11 (4.1)	8 (3.5)	
Wound seroma	7	4	
Wound infection	4	4	
Grade 2	15 (5.5)	17 (7.4)	
Intraperitoneal abscess	5	4	
Voiding difficulty	3	7	
Prolonged ileus	2	2	
FUO	2	3	
Acute kidney injury	1	0	
Pneumonia	1	0	
PMC	1	0	
Arrhythmia	0	1	
30-Day mortality	0	0	
Time to resuming liquid intake (day)	1.30 (0–5)	1.20 (1–5)	0.093
Time to resuming soft diet intake (day)	2.24 (1–7)	1.66 (1–6)	<0.001
Postoperative hospital stay (day)	3.22 (1–18)	2.77 (1–10)	0.001
Readmission	4 (1.5)	4 (1.7)	0.820

Values are presented as number (%), number only, or mean (range).
SPLS, single-port laparoscopic surgery; MPLS, multiport laparoscopic surgery; FUO, fever of unknown origin; PMC, pseudomembranous colitis.

(49.8% *vs.* 19.9%, P < 0.001). There were no conversions to open surgery in either group. The mean operation time was 4.6 minutes longer in the pre-COVID-19 pandemic group (36.23 minutes *vs.* 31.62 minutes, P = 0.001). The overall 30-day postoperative complication rate was not significantly different between the groups (9.6% *vs.* 10.8%, P = 0.650). Postoperative complication severity according to the modified Clavien-Dindo classification was similar in both groups (grade I, 4.1% *vs.* 3.5% and grade II, 5.5% *vs.* 7.4%; P = 0.447). There was no 30-day mortality in either group. The mean time taken to resume liquid intake was similar in both groups (1.30 days *vs.* 1.20 days, P = 0.093), but the mean time taken to resume a soft diet intake was longer in the pre-COVID-19 pandemic group than in the post-COVID-19 pandemic group (2.24 days *vs.* 1.66 days, P < 0.001). Therefore, the postoperative length of hospital stay was also longer in the pre-COVID-19 group (3.22 days *vs.* 2.77 days,

P = 0.001). There was no difference in the readmission rate between the groups (P = 0.820) (Table 2).

DISCUSSION

The present study revealed that the COVID-19 pandemic did not change the healthcare-seeking behavior of patients who had acute appendicitis in Chuncheon, Korea. In addition, there was no significant change in perioperative outcomes among patients with appendicitis after the onset of the COVID-19 pandemic compared to those in the pre-pandemic period.

The differences in the time interval from symptom onset to visiting the emergency department, the degree of inflammation, postoperative complications, and time to resume diet were compared among patients with acute appendicitis during the pre- and post-COVID-19 pandemic periods. Baseline patient characteristics, proportions of complicated appendicitis, and inflammatory markers at admission were not significantly different between the pre- and post-COVID-19 pandemic groups (all P > 0.05). Similarly, a previous study reported that preoperative inflammatory markers, including WBC and CRP levels, were not significantly different [11]. Turanli and Kiziltan [8] also reported no clear increases in the number of patients with perforated appendicitis diagnoses during the COVID-19 pandemic period. A multicenter cohort study by Huijgen et al. [12] reported no observed differences in the number of appendectomies and the proportion of patients with complex appendicitis. However, some studies found that the COVID-19 pandemic period was associated with significant increases in the incidence of complicated appendicitis [7,13-15]. Another study showed that WBC and CRP levels were also significantly higher in patients with acute appendicitis during the COVID-19 pandemic than in those before the pandemic [16]. During the COVID-19 pandemic, patients were concerned about newly acquiring the SARS-CoV-2 infection when attending the hospital, and containment and closure policies in some communities also made it difficult for them to visit the hospital. Therefore, they hypothesized that a delayed diagnosis due to limited hospital access could result in more complicated appendicitis [13-15]. There are a few possible explanations for the unchanged presentation of patients with acute appendicitis in the present study. First, in the early stages of the pandemic, COVID-19 was spreading in a specific region (Daegu, Korea), while the rate of spread was relatively slow in other regions. In regions other than Daegu, the burden on medical institutions was comparatively lighter, making them easier to access. Second, owing to the comparatively limited lockdown and the stability of the medical systems in South Korea, the referral numbers for acute appendicitis might not have been reduced. Choi et al. [17] found no significant change in the incidence of acute appendicitis during the COVID-19 pandemic after comparing pre- and intra-pandemic data from the Korean National Health Insurance Service. They suggested that the similarity in medical visit rates for acute appendicitis between the 2 periods may be related to the stability of medical systems.

Moreover, there was no difference in the time between symptom onset and hospital arrival between the 2 groups. This suggests that there was no tendency to delay visits to the emergency department due to fear of infection. In contrast, several studies have reported prolonged times to hospital visits from symptom onset during the pandemic [2,16,18,19]. They suggested that the reason for this delay is patient concern about COVID-19 transmission at the hospital. However, the finding that the time between symptom onset and emergency department visit remained unchanged in other studies was consistent with ours [20-22].

Although controversial, the present study suggests that the pandemic did not affect the healthcare-seeking behavior of patients who had appendicitis. Additionally, the time interval between hospital arrival and the start of surgery did not differ between the 2 groups. This suggests that confirmatory testing for SARS-CoV-2 infection status during the pandemic did not cause a significant delay. The results of the PCR test for COVID-19 were reported during preoperative preparation, so the time interval between hospital arrival and the start of the operation was not affected. In addition, our hospital was not a COVID-19-dedicated hospital, and the impact of COVID-19 on hospital capacity was minimal. However, 1 study found that the time spent in the emergency department before surgery was significantly longer in the pandemic group (519.11 ± 486.57 minutes *vs.* 705.27 ± 512.59 minutes, P < 0.001) [23]. In our study, the 30-day postoperative complication rates and severity were similar between the 2 groups. This might have occurred because of the unchanged duration between symptom onset and the emergency department visit and between the emergency department visit and surgery, as well as the unchanged proportion of complicated appendicitis cases.

The present study revealed that SPLS was performed in fewer cases in the post-COVID-19 pandemic group than in the pre-COVID-19 pandemic group. This might have been because the overall preference for SPLS has decreased over time at our institution, with a significant decrease in that for acute appendicitis. A previous randomized controlled trial reported that SPLS required a longer operation time, had a delayed postoperative time to functional recovery, and longer postoperative hospital stay compared to MPLS [24]. In our study, as the proportion of SPLS decreased, the operation time and postoperative hospital stay were shorter post-COVID-19.

There were a few limitations to the present study. First, its retrospective design has a risk of selection bias. Second, the proportions of the number of SPLSs and MPLSs performed differed between the 2 periods, and consequently, some

operative outcomes also differed between groups. To identify the possible associations among the type of operation performed (SPLS *vs.* MPLS), period during which the operation was performed (pre- vs. post-COVID-19 pandemic), sex (male vs. female), BMI (<24 kg/m^2 *vs.* >24 kg/m^2), ASA PS grade (I/II *vs.* III/IV), and type of appendicitis (uncomplicated *vs.* complicated), we conducted multivariate analyses for operation time, postoperative complications, and postoperative hospital stay (data not shown). In these multivariate analyses, SPLS was an independent risk factor for longer operation time and complicated appendicitis was an independent risk factor for postoperative complications. SPLS and complicated appendicitis were independent risk factors for longer hospital stay. However, these multivariate analyses revealed that the period during which the operation was performed did not affect the operation time, postoperative complications, or postoperative length of hospital stay. Third, our hospital was not a COVID-19-dedicated center, and COVID-19-positive patients in the emergency department were transferred to a COVID-dedicated center during our study period. Hence, there were no COVID-19 patients in our data registry. In addition, there were few COVID-19-positive patients in our city (less than 10 patients per day during our study period). Therefore, our observations for the environment of the health care system and medical burden in our city may not be generalized for regions that experienced COVID-19 breakouts. Nevertheless, this study is meaningful in analyzing the clinical outcomes of laparoscopic appendectomy in a medical environment with psychological stress and increased medical burden due to the COVID-19 pandemic.

In conclusion, there were no differences between the pre- and post-pandemic groups in terms of the time taken to visit the emergency department after symptom onset, the type of appendicitis, or postoperative complications among patients who had undergone laparoscopic appendectomy for acute appendicitis. Therefore, even in the pandemic era, laparoscopic appendectomy can be performed safely and effectively.

ACKNOWLEDGEMENTS

Fund/Grant Support

None.

Conflict of interest

No potential conflict of interest relevant to this article was reported.

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Author Contribution

Conceptualization, Formal Analysis, Investigation, Methodology, Project Administration: BMK, HK
Writing – Original Draft: BMK, HK
Writing – Review & Editing: BMK, HK

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