Association between the Computed Tomography Findings and Operative Time for Interval Appendectomy in Children

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Abstract

Purpose: The purpose was to evaluate the association between operative time and findings noted on computed tomography (CT) immediately before interval appendectomy. **Materials and Methods:** Forty-two children who underwent CT before interval appendectomy were included. We evaluated the association between operative time and these image findings: (1) appendicolith, (2) increased intra-abdominal fat density around the appendix, (3) location of the appendix, (4) ascites, (5) abscess formation and (6) maximum appendix outer wall diameter. Appendix location was classified as (#1) just below the anterior abdominal wall; (#2) retrocaecal or retro-ascending colon and (#3) pelvic. Results were analysed using Pearson's correlation coefficient or Mann–Whitney U test. **Results:** The mean patient age and operative time were 116.24 ± 38.66 months (range, 31–195) and 67.76 ± 31.23 min (range, 30–179), respectively. Ascites was detected in only one case, and no abscess occurred in any patient; therefore, these findings were not analysed. Factors that significantly prolonged the operative time included increased intra-abdominal fat density around the appendix (absent, 59.43 ± 22.14 [range, 30–108] vs. present, 84.43 ± 40.13 [range, 32–179] min; $P = 0.03$) and retrocaecal or retro-ascending colon appendix (location 1, 40.83 ± 8.35 [range, 30–50]; location 2, 99.25 ± 18.56 [range, 74–135]; location 3, 64.54 ± 30.22 [range, 30–179] min; $P < 0.01$). There was a weak but significant association between maximum appendix outer wall diameter and operative time ($R = 0.353$; $P = 0.02$). **Conclusion:** These pre-operative CT findings are important predictors of operative time for interval appendectomy. Radiologists and surgeons should use these specific image findings to predict the operative time and need for additional procedures during an interval appendectomy.

Keywords: Acute appendicitis, computed tomography, interval appendectomy, operative time, transumbilical laparoscopic-assisted appendectomy

Introduction

Appendicitis is the most common cause of acute abdominal pain requiring surgical intervention.[1] After the diagnosis of appendicitis, the surgeons and physicians consider whether an early surgical intervention, delayed surgical intervention with antibiotic treatment first (interval appendectomy) or antibiotic treatment alone should be provided.[1-6] An interval appendectomy is aimed at achieving fewer surgical complications and a shorter post-operative hospital stay compared to those noted for an emergency appendectomy.[7-9]

Computed tomography (CT) is a useful method for determining whether a patient is a suitable candidate for interval appendectomy[7,8] and can also be used to evaluate abscess formation after acute appendicitis.[10,11] In addition, previous studies reported that the operative time for appendectomy could be predicted based on the findings detected in CT or ultrasound images obtained before emergency appendectomy.[12,13] To the best of our knowledge, however, there are no studies reporting on whether the CT findings can predict the operative time for an interval appendectomy. This study aimed to evaluate the association between the pre-operative CT imaging findings and the operative time for interval appendectomy. If the factors affecting the operative time are determined, radiologists can use this knowledge to inform the surgeons of how the operation may be impacted.

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Materials and Methods

Patients

This retrospective study was approved by the ethics committee of our institution and was performed in accordance with the tenets of the Declaration of Helsinki; furthermore, the need for obtaining informed consent from the patients or their guardians was waived.

We reviewed the medical records at our hospital from May 2013 to May 2020 and identified 50 children who underwent CT before an interval appendectomy performed using the transumbilical laparoscopic-assisted appendectomy (TULAA) technique. For these children, the exclusion criteria were as follows: (1) interval appendectomy was not performed because of the recurrence of appendix inflammation after CT; (2) underlying disease; (3) CT was performed without contrast enhancement and (4) the medical records could not be reviewed.

Indication of interval appendectomy

An interval appendectomy was performed based on the consensus among two paediatric surgeons (with at least 2 years of experience) after reviewing the CT images and physical findings. Informed consent for the surgical procedure was obtained from the parents of the patient. The imaging findings used to determine if an interval appendectomy was indicated were abscess formation and appendix rupture.[12,14,15]

Modality

All CT investigations were performed using the 4- or 64-detector CT scanners (Definition AS+; Siemens Healthcare, used from 2013 to 2017; Definition Wedge; Siemens Healthcare, used from 2017 to 2020). All examinations were performed with a low-dose technique using either a weight-based table or an automated tube current modulation to determine the tube current (in mA). All CT scans were performed at 80–120 kV, which was automatically adjusted based on the patient's physique. The standard section slice thickness was 3 mm. The amount of contrast material (300 mg iodine/mL) used was 2 mL/kg with a maximum volume of 100 mL. The contrast material was injected either automatically or manually. The CT examination was always performed in the portal or delayed phase and not in the arterial phase. The CT dose index for all patients was 2.58 ± 3.37 mGy (range, 0.85–16.35 mGy) with a 32-cm phantom.

Computed tomography findings

The presence of the following CT findings[16-20] on a 1600 × 1200 picture archiving and communication system (PACS) monitor (GE Healthcare) was evaluated: (1) appendicolith [Figure 1]; (2) increased intra-abdominal fat density around the appendix [Figures 1 and 2]; (3) location of the appendix [3 locations; Figures 1-3]; (4) ascites; (5) abscess formation (walled-off fluid collection) and (6) maximum outer wall diameter of the appendix. The appendix location was classified into one of the following three locations: (1) just below the anterior abdominal wall [Figure 2]; (2) in the retrocaecal or retro-ascending colon [Figure 1] and (3) in the pelvis, on the ventral side covered by the small intestine [Figure 3].

Review process

Two radiologists, with 15 and 10 years of clinical experience, retrospectively reviewed all images on a PACS and achieved a consensus during the review process; the radiologists were blinded to the surgical, physical or other imaging parameters.

Surgical procedure, surgeon and operative time

TULAA was performed through a single vertical umbilical incision (26 mm). The wound retractor (Lap Protector 504; Hakko Medical, Nagano, Japan) was inserted through the incision and a silicon cap (EZ access 504, Hakko Medical) was mounted to the lap protector. Three reusable 5-mm ports (mini-mini Trocar Sleeves; Hope Denshi, Chiba, Japan) were placed in the EZ access system. After the establishment of pneumoperitoneum, the tip of the appendix was grasped and if possible, exteriorised through the umbilical incision. The appendix was resected outside the abdominal cavity, as in open surgery. The appendiceal stump and caecum were returned inside the abdominal cavity. For safety concerns, additional ports were added, if deemed necessary by the surgeon. We recorded the surgical experience of the surgeon and first assistant (in years) and the operative time, defined as the time from the start of skin incision to the end of incision closure (in minutes).

Statistical analysis

Descriptive statistics are expressed as mean ± standard deviation for continuous variables and as frequency and percentages for categorical variables. The association between the operative time and patient characteristics was evaluated using Pearson's correlation coefficient or Mann–Whitney U test, depending on the type of variable (i.e., continuous or categorical variable). Continuous variables included patient age, height, weight, body mass index, interval between symptom onset and appendectomy and maximum outer wall diameter of the appendix. Categorical variables included sex, appendicolith, increased intra-abdominal fat density around the appendix, appendix location, ascites and abscess formation. For all tests, a P value of 0.05 was considered significant. All data were analysed using SPSS (Version 24; IBM, Armonk, NY, USA).

Results

Participant characteristics

Of the 50 children who underwent a CT scan before an interval appendectomy performed using the TULAA technique, eight were excluded based on the following exclusion criteria: (1) recurrence after CT examination (one case); (2) acute leukaemia as an underlying disease (one case); (3) CT performed without contrast enhancement (two cases) and (4) medical records could not be reviewed (four cases). Ultimately, 42 cases were included in this study. Table 1 shows the patient characteristics. The average number of days between the CT scan and interval appendectomy was 3.95 ± 3.39 (range, 0–10).

Analysis of the association between the operative time and patient demographic characteristics

The association between the operative time and various patient demographic characteristics is shown in Tables 2 (continuous variables) and 3 (categorical variables). Ascites was detected on the CT scan in only one case, and abscess formation was not detected in any of the cases. Therefore, the relationship between these findings and operative time was not evaluated. The presence of intra-abdominal fat density around the appendix and appendix location in the retrocaecal and retro-ascending colon were factors that significantly prolonged the operative time. There was a weak, but significant, association between the maximum outer wall diameter of the appendix and operative time. Sex, patient age, height, weight, body mass index and presence of an appendicolith were not associated with the operative time (all $P > 0.05$).

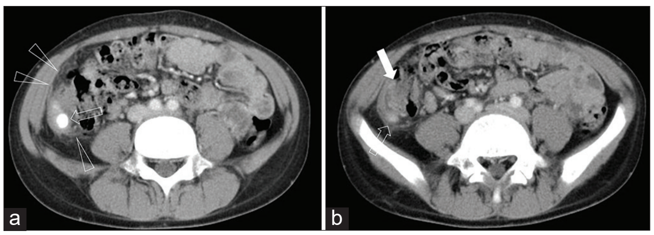

Figure 1: A 121-month-old female patient was 140 cm tall and weighed 34 kg. The operative time was 135 min. The interval between symptom onset and appendectomy and between computed tomography and appendectomy was 113 days and 7 days, respectively. (a) Axial computed tomography image shows that the appendicolith (open arrow) and appendix are surrounded by increased intra-abdominal fat density (arrow heads) and the maximum outer diameter of the appendix is 15 mm. (b) Axial computed tomography image shows that the appendix (open arrow) is located in the retro-ascending colon (white arrows). Appendix location is classified as 2

Discussion

Our study indicates that increased fat density around the appendix and appendix location in the retrocaecal or retro-ascending colon is associated with the prolonged operative time during an interval appendectomy in children. These CT findings could be useful for radiologists and paediatric surgeons for predicting the operative time of an interval appendectomy before beginning the operation. In addition, there was a weak, but significant association between the maximum outer wall diameter of the appendix and operative time.

The increased intra-abdominal fat density around the appendix may result from adhesions between the appendix and surrounding tissues; in such cases, additional surgical procedures, such as adhesiolysis, are needed.[12,21-23] Such additional surgical procedures may then account for the increased operative time and increase the risk of bleeding.[24] Therefore, this imaging finding may aid surgeons in preparing for complications.

Previous studies investigating emergency appendectomy procedures have reported that in cases where the appendix is located in the pelvis and is surrounded by the small intestine, a longer operative time is required.[12] In this study, however, we found that the location of the appendix at this site was not associated with a longer operative time. In interval

Table 1: Patient characteristics and surgeon experience

Patient characteristics	
Total number of patients (*n*)	42
Sex, *n* (%)	
Female	17 (40.5)
Male	25 (59.5)
Patient age (months)	116.24±38.66 (range, 31−195)
Height (cm)	134.13±19.35 (range, 88−183.5)
Weight (kg)	30.84±11.31 (range, 12.5−67.1)
BMI (kg/m^2)	16.49±1.81 (range, 13.46−20.63)
Interval between symptom onset and appendectomy (days)	130.43±43.66 (range, 59−242)
Interval between computed tomography and appendectomy (days)	3.95±3.39 (range, 0−10)
Operative time (min)	67.76±31.23 (range, 30−179)
Maximum outer wall diameter of appendix (mm)	6.65±2.93 (range, 2.8−15.0)
Appendicolith, presence, *n* (%)	11 (26.2)
Ascites, presence, *n* (%)	1 (2.4)
Abscess formation, presence, *n* (%)	0 (0)
Increased intra-abdominal fat density around the appendix	14 (33.3)
Location of appendix*	
1: Just below the anterior abdominal wall	6 (14.3)
2: In retrocaecal or retro-ascending colon	8 (19.0)
3: In the pelvis, on the ventral side covered by the small intestine	28 (66.7)

*Location of the appendix was classified as follows: 1) just below the anterior abdominal wall (appendix left the caecum and ran anteriorly just below the anterior abdominal wall); 2) in the retrocaecal or retro-ascending colon (appendix left the caecum and ran posteriorly behind the ascending colon) and 3) in the pelvis, on the ventral side covered by the small intestine (appendix left the caecum and ran towards the pelvis). BMI: Body mass index appendectomy cases, abscesses usually form, and severe adhesions occur around the appendix.[5,13,25,26] In contrast to the small intestine, which freely moves in the abdominal cavity, the large intestine is located within the retroperitoneal space.[27] Colonic inflammation was reported to result in severe adhesion, and these cases occasionally required conversion of the surgical approach from laparoscopic colectomy to open colectomy.[28] Severe adhesions may tend to develop more frequently around the fixed large intestine than around the unfixed small intestine.

Although the severity of acute appendicitis was not associated with the maximum outer wall diameter of the appendix,[15] grasping and resecting a swollen appendix during surgery requires more care to prevent rupture than that of an appendix that is not swollen. Therefore, in our cohort, an enlarged appendix could have prolonged the operative time.

In adult patients, a higher body mass index prolongs the operative time.[29,30] Obesity is defined as a body mass index > 30 kg/m^2;[30] in our study, the highest body mass index was 20.63 kg/m^2. Therefore, it was not possible to investigate the association between obesity and operative time in this study.

Table 2: Results of the univariate analysis of the association between the operative time and continuous variables

Continuous variables	*r* (95% CI)	*P*
Age	0.202 (−0.109- 0.477)	0.20
Height	0.224 (−0.086- 0.494	0.15
Weight	0.260 (−0.048- 0.523)	0.10
BMI	0.239 (−0.070- 0.506)	0.13
Interval between symptom onset and interval appendectomy	0.132 (−0.179- 0.419)	0.40
Maximum outer wall diameter of appendix	0.353 (0.055- 0.593)	0.02

CI: Confidence interval, BMI: Body mass index

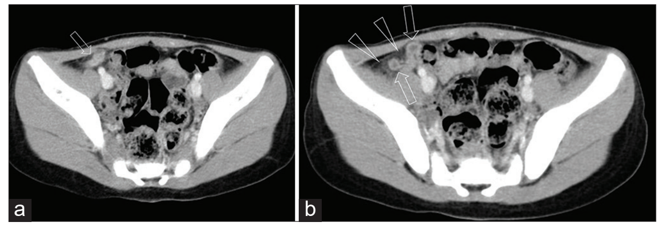

Figure 2: An 81-month-old female patient was 115.3 cm tall and weighed 15.19 kg. The operative time was 45 min. The intervals between symptom onset and appendectomy and between computed tomography and appendectomy were 106 days and 7 days, respectively. (a) Axial computed tomography image shows that the appendix (open arrow) is located just below the anterior abdominal wall. Appendix location is classified as 1. An appendicolith is not detected. (b) Axial computed tomography image shows that the appendix (open arrows) is surrounded by increased intra-abdominal fat density (arrow heads), and the maximum outer diameter of the appendix is 8 mm (double-headed arrow)

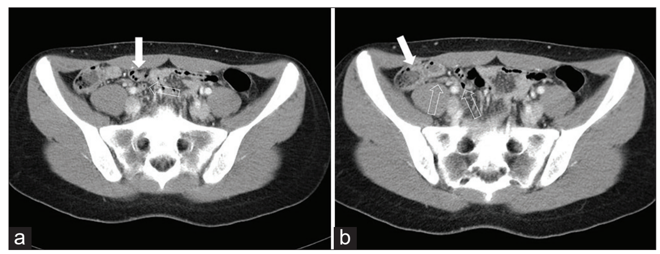

Figure 3: A 175-month-old female patient was 148.5 cm tall and weighed 45.5 kg. The operative time was 30 min. The intervals between symptom onset and appendectomy and between computed tomography and appendectomy were 109 days and 5 days, respectively. (a) Axial computed tomography image shows that the appendix (open arrow) runs towards the pelvis. The ventral side is covered by the small intestine (white arrow). Appendix location is classified as 3. (b) Axial computed tomography image shows that the appendix leaves the caecum (white arrow). The appendix (open arrows) is not surrounded by increased intra-abdominal fat density, and the maximum outer diameter of the appendix is 4.7 mm

Table 3: Results of the univariate analysis of the association between the operative time and categorical variables

Categorical variables	Operative time (min)	*P*
Sex		
Female	60.88±35.33 (range, 30−179)	0.08
Male	72.44±27.89 (range, 30−135)	
Appendicolith		
Absent	65.31±63.52 (range, 30−179)	0.29
Present	75.60±29.68 (range, 32−135)	
Increased intra-abdominal fat density around the appendix		
Absent	59.43±22.14 (range, 30−108)	0.03
Present	84.43±40.13 (range, 32−179)	
Location of appendix*		
1: Just below the anterior abdominal wall	40.83±8.35 (range, 30−50)	0.07 (1 vs. 3)
2: In retrocaecal or retro-ascending colon	99.25±18.56 (range, 74−135)	<0.01 (1 vs. 2)
3: In the pelvis, on the ventral side covered by the small intestine	64.54±30.22 (range, 30−179)	0.01 (3 vs. 2)

*Location of the appendix was classified using three locations: Location 1: Just below the anterior abdominal wall (appendix left the caecum and ran anteriorly just below the anterior abdominal wall); Location 2: in the retrocaecal or retro-ascending colon (appendix left the caecum and ran posteriorly behind the ascending colon); Location 3: In the pelvis, on the ventral side covered by the small intestine (appendix left the caecum and ran towards the pelvis)

There are some limitations of this study. First, a small number of patients were included in this study and the degree of appendicitis severity in the acute phase was not evaluated. Thus, additional studies with a larger number of patients with similar severity of acute appendicitis are required to confirm our preliminary findings. Second, the patient is exposed to radiation during CT. Consequently, ultrasound or magnetic resonance imaging is usually recommended as the first modality of examination for children with suspected appendicitis.[15,31] Therefore, additional studies using other imaging techniques are warranted.

Conclusion

Our study indicated that increased fat density around the appendix and appendices located in the retrocaecal or retro-ascending colon was associated with a longer operative time for interval appendectomy procedures performed in children. In addition, we found that the maximum outer wall diameter of the appendix might also be associated with the increased operative time. These CT findings are important pre-operative predictors of the requirement for additional surgical procedures, such as adhesiolysis, and of the operative time of interval appendectomy. Radiologists and surgeons should use these specific imaging findings to help predict the operative time and the need for additional procedures during an interval appendectomy.

Informed consent

This retrospective study was approved by the ethics committee of our institution, and informed consent was waived.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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