Original article

Pediatric appendicitis or not: A retrospective cohort study from a single institution-our management and factors determining the disease

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Abstract

Background: Appendicitis in children is a common health problem, but its management still has some controversial aspects.

Objectives: This study aimed to assess our treatment guidelines and determine factors in differentiating children with acute appendicitis from other diseases.

Methods: Pediatric surgery consultations for suspected appendicitis from October 2019 to October 2021 was retrospectively studied. The treatment guidelines of children with suspected appendicitis were elucidated. Moreover, factors identifying the diagnosis of appendicitis were analyzed using multi-variate logistic regression.

Results: Ninety-one children were consulted for suspected appendicitis. Forty-one children (45.1%) were promptly successfully treated without observation or ultrasonography, except one negative appendectomy (2.4%). The other 50 children (54.9%), showed equivocal clinical symptoms and signs, requiring further management either overnight observation (11 cases) or ultrasonography (39 cases). Following observation, 7 patients (63.6%) were successfully treated without further imaging studies. On the contrary, after abdominal ultrasound (39 cases), appendices or other intra-abdominal pathologies could be demonstrated, leading to definitive diagnosis and treatment in 17 patients (43.6%), except one false-positive case (5.9%). Only 6 patients had computed tomography (CT) scintigraphy following equivocal ultrasound findings. Accordingly, the treatment guidelines achieved an overall 93.4% accuracy. Clinical complaints were statistically different as majority of cases with appendicitis having migratory pain (46.3%, $P < 0.001$). With logistic regression analysis, it was revealed that migratory pain, right lower quadrant (RLQ) tenderness, elevated white blood cell (WBC) count and high proportion of neutrophils were significantly associated with appendicitis.

Conclusion: Pediatric appendicitis is occasionally arduous to diagnose. By minimizing the utilization of CT scan, our treatment guidelines accomplish high accuracy. Careful history taking, thorough physical examination, and basic laboratories were crucial for accurate diagnosis.

Keywords: Appendicitis, computed tomography, diagnosis, overnight observation, ultrasonography.

Acute appendicitis is one of the most common surgical conditions requiring urgent surgery in children. [1, 2] Despite the commonness of disease, the diagnostic approach remains varied among centers. [3] Clinical findings along with initial laboratory values often lead to an accurate diagnosis. However, there are several patients with equivocal presentations. These require either further management or investigations. The means of obtaining definite diagnosis, in addition to clinical acumen, include overnight observation, ultrasonography, and computed tomography.[4] While hospitals in some regions usually use a computed tomography (CT) scan in patients suspected of acute appendicitis [5, 6], others rely on clinical presentations and choose a CT scan as the last modality due to radiation exposure concerns. [7 - 10]

The aims of this study were to evaluate how efficient our current management was and to identify factors that distinguish children suffering from acute

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appendicitis from other non-surgical conditions. We performed a retrospective chart review of consulted patients in both outpatient and inpatient departments and correlated them with management and outcomes.

Materials and methods

Study cohort

After obtaining the certificate of approval from the Institutional Review Board (IRB), Faculty of Medicine, Chulalongkorn University; (IRB no 992/64), we conducted a retrospective review of patients, ≤ 15 years of age, who had surgical consultation for suspected acute appendicitis from October 2019 to October 2021. The study protocol was performed in accordance with the relevant guidelines and regulations. Since the study was an entirely retrospective observational fashion, waived informed consent was obtained from the Institutional Review Board (IRB), Faculty of Medicine, Chulalongkorn University.

The data were extracted from medical records. A total of 95 patients were identified during the study period. After four patients with unstable illnesses and serious underlying diseases were excluded, there were 91 patients in the final recruitment. Patients' information was collected including gender, age, symptoms, clinical laboratory values, imaging modalities and pathology reports. The primary outcome was the accuracy of our management in the diagnosis of appendicitis. The secondary outcome was clinical factors that distinguished patients with appendicitis from patients with non-appendicitis or non-surgical conditions. The patients were categorized into two groups: diagnosis by clinical acumen and equivocal clinical needing further tools. The diagnosis of appendicitis by clinical acumen was defined by history of gastrointestinal irritation (nausea, anorexia) and migratory pain to right lower quadrant (RLQ), maximal point of tenderness at RLQ, and leukocytosis. The diagnostic tools include ultrasonography and overnight observation.

Accuracy of management confirmed by the pathology report of appendicitis including acute appendicitis, acute suppurative appendicitis with/without perforation, and acute necrotizing appendicitis. Negative appendicitis was defined by a pathologically normal appendix and/or lymphoid hyperplasia of the surgically removed appendix in patients initially suspected of acute appendicitis. The negative appendectomy rate was calculated by dividing the number of negative appendicitis cases by the total number of patients suspected acute appendicitis underwent appendectomy.

Statistical analysis

We used descriptive statistics, chi-square, unpaired *t* - tests, and K independent sample tests for median test. Logistic regression was used to evaluate factors determining diagnosis of appendicitis. We conducted all analyses using IBM SPSS Statistic V22 and considered $P < 0.05$ to be statistically significant. Data were expressed as median and interquartile range. All data generated or analyzed during this study are included in this published article and its supplementary information files.

Results

There were 91 children (44 males and 47 females) with abdominal pain who had a surgical consultation to be evaluated for suspected appendicitis. All patients were clinically stable and co-operative. Patients were categorized into two groups: diagnosis by clinical acumen and equivocal clinical needing further investigation. In the first group (diagnosis by clinical acumen), 41 out of 91 patients (45.1%) were successfully managed without overnight observation or ultrasonography. However, there was one negative appendectomy for this group of patients. In the second group (equivocal presentation), patients with equivocal presentations were further divided into two subgroups: overnight observation or ultrasonography. **Figure 1** represented our current management guideline of patients consulted for evaluation of acute appendicitis together with the results. Demographic data, together with presenting signs and symptoms categorized by management were shown in **Table 1.**

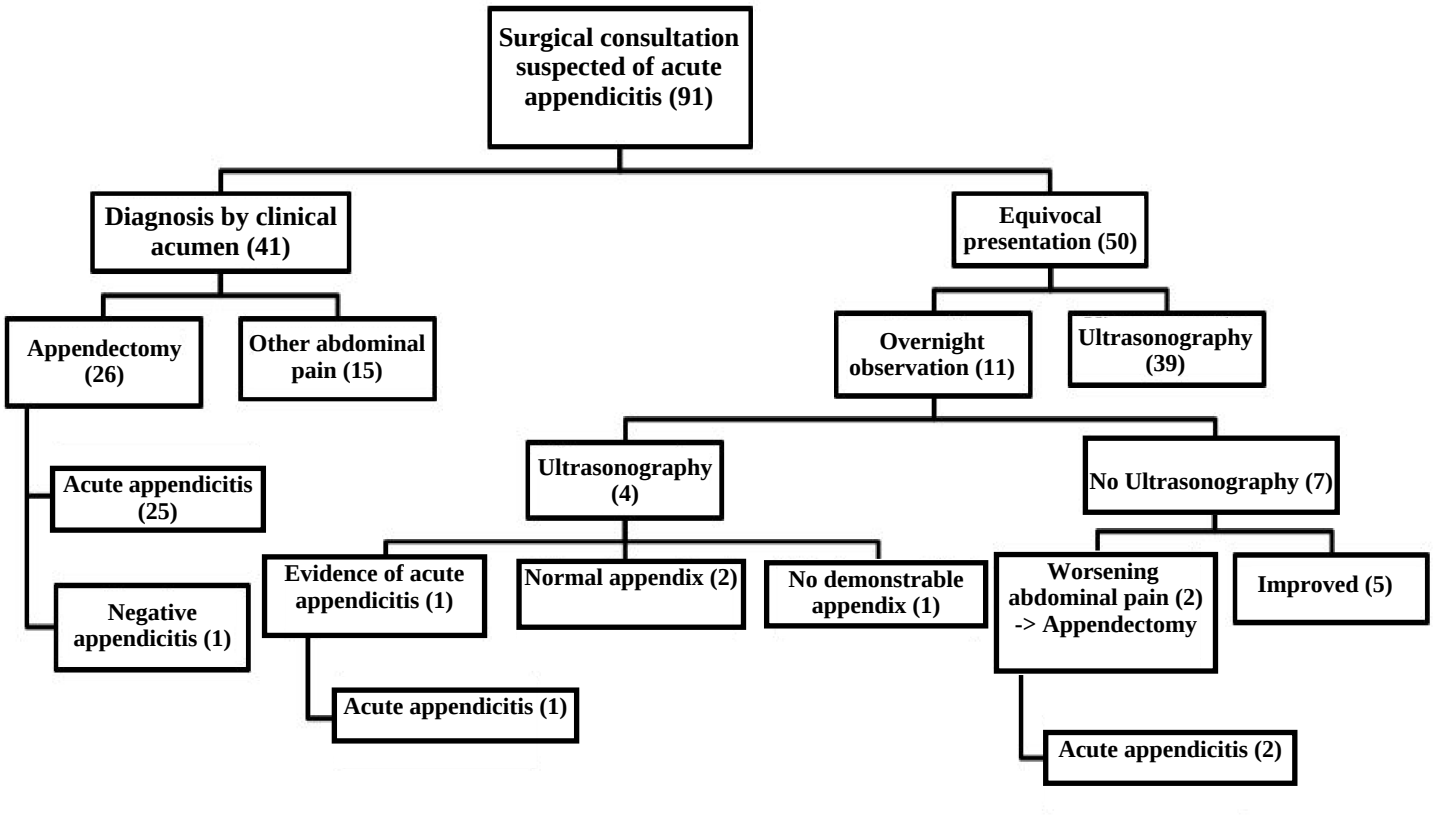

Figure 1. The results of our management guideline of patients consulted for evaluation of acute appendicitis.

Table1. Demographic data, presenting signs and symptoms (number of patients).

	Clinical acumen (n = 41)	**Equivocal presentation (n = 50)**	***P* - value**
Demographic data			
Gender (male)	23 (56.1%)	21 (42.0%)	0.181
Age (years)	10.0 (6.9 - 11.8)	9.9 (7.2 - 12.7)	0.728
Weight (kg)	37.0 (21.0 - 45.1)	41.0 (19.7 - 50.4)	0.442
Weight for age (Z-score)	0.3 (-0.7 - 1.0)	0.195 (-1.0 - 1.4)	0.76
Presenting signs and symptoms			
Onset of symptoms (median, hours)	24 (9.5 - 36.0)	24 (5.0 - 72.0)	0.166
Migratory pain	18 (43.9%)	6 (12.0%)	< 0.001
Fever	14 (34.1%)	15 (30.0%)	0.673
Nausea/ Emesis	27 (65.9%)	30 (60.0%)	0.566
RLQ tenderness	33 (80.5%)	41 (82.0%)	0.854
White blood cell counts ($x10^3$)	14.7 (11.4 - 17.7)	13.3 (10.0 - 16.2)	0.116
Neutrophil counts (≥ 75.0%)	82.7 (72.4 - 86)	75.7 (66.9 - 82.9)	0.016
Pediatric appendicitis score	5 (4 - 7)	5 (3 - 6)	0.041

There were 50 patients with equivocal clinical findings. Subsequently 11/50 patients were admitted for observation and serial physical examination. Adjunct ultrasonography was performed on 4/11 with one positive for acute appendicitis. Among the other 7/11 patients, there were 2 children with progressive abdominal pain, obviously consistent with appendicitis, who later underwent appendectomy.

Patients with equivocal presentations undergoing abdominal ultrasonography following consultation

On the contrary, 39/50 patients were requested for abdominal ultrasonography promptly after evaluation by pediatric surgeons. They were categorized into 4 groups, as shown in **Figure 2,** as follows: evidence of appendicitis (n = 11), normal appendices (n = 11), no demonstrable appendix (n = 14), and other pathologies (n = 3). As it appeared in **Figure 2**, in the first group, 11/39 patients were diagnosed with acute appendicitis by abdominal ultrasound and underwent appendectomy. However, there was one negative appendectomy in this group. Additionally, 11 patients had normal appendices. There was one patient in a normal ultrasound group who had persistent pain and underwent appendectomy which the pathology report showed reactive lymphoid hyperplasia. In the third group, 14/39 patients, appendices could not be demonstrated by ultrasono-graphy. Five patients were requested for computed tomography and none of them were diagnosed with acute appendicitis. Eventually, 2/14 patients had progressive abdominal pain and proceeded for appendectomy. 4/14 patients were admitted into the hospital and one of them had worsening abdominal pain and underwent appendectomy. In the fourth group, other pathological diseases were found on ultrasonography in 3 patients including right ovarian cyst with and without complication.

Diagnostic test of abdominal ultrasonography

To evaluate all cases having an abdominal ultrasound (43/91) **(Figure 3)**, the sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) were calculated and shown in **Table 2**. Ultrasonography could identify appendices and other intra-abdominal pathology leading to definitive management of 17 patients. Computed tomography was requested in 6 patients following equivocal ultrasound findings. All 6 children benefited from CT scan.

Diagnostic values of our management guideline

Of the 91 patients, 41(45.1%) patients were diagnosed with appendicitis. Overall negative appendectomy rate was 3.3% (3/91). There were none of the patients who revisited or readmitted and later diagnosed with acute appendicitis. The accuracy for diagnosing appendicitis in our study was 94.5%. Overall CT scan rate was 6.6%.

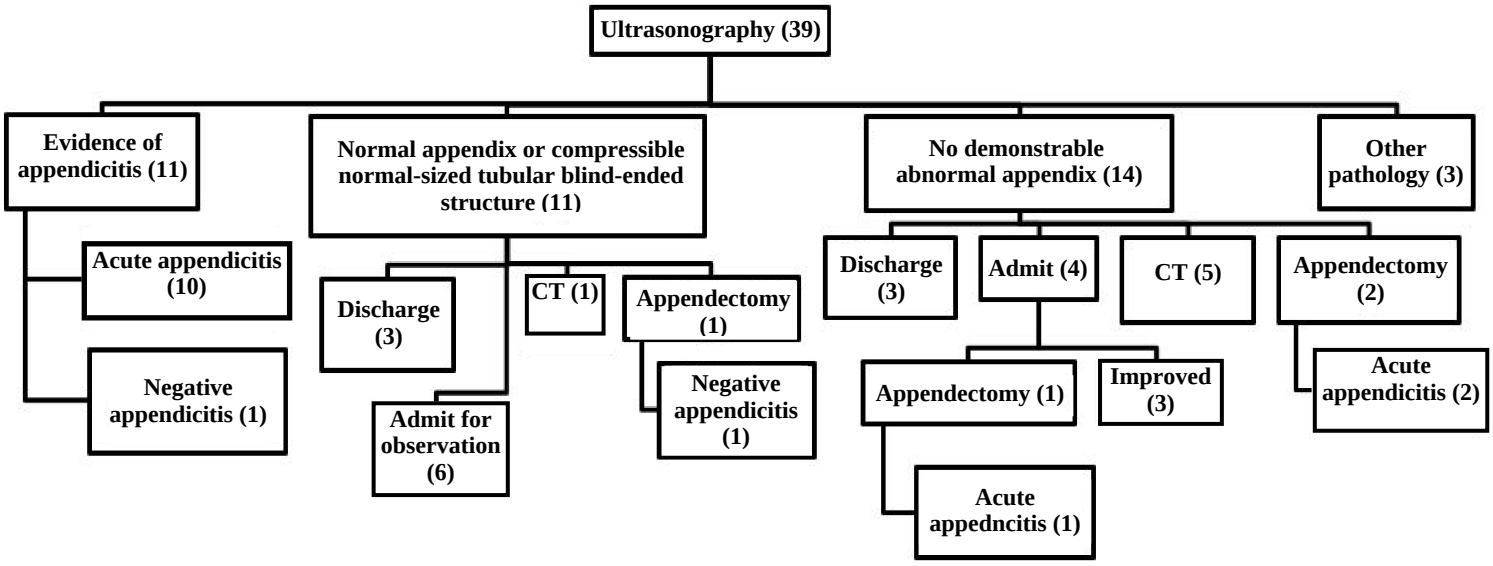

Figure 2. Patients who were requested for ultrasound promptly after pediatric surgeons' evaluation.

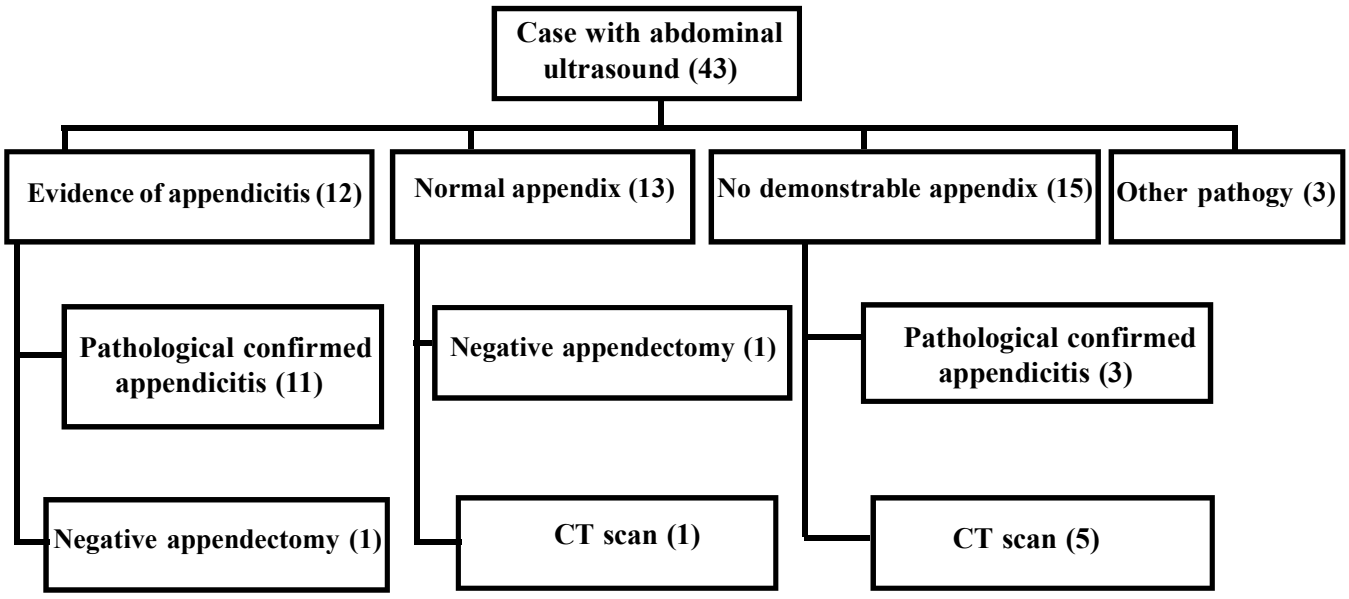

Figure 3. Overall 43 patients with abdominal ultrasound.

Table 2. Sensitivity, specificity, PPV, and NPV in patients undergoing abdominal ultrasonography.

Ultrasonography (n = 43)	Appendicitis	Non appendicitis
Test positive	11	1
Test negative	3	28
Sensitivity	78.6%	
Specificity	96.6%	
Positive predictive value (PPV)	91.7%	
Negative predictive value (NPV)	90.3%	

Factors distinguishing patients with appendicitis from patients with non-appendicitis

The secondary outcome compared characterization between patients with appendicitis and patients with other non-surgical abdominal pain. Demographic data of the patients was shown in **Table 3**. There was no demographic difference between the two groups. In view of clinical complaints, the majority of cases with appendicitis had migratory pain (46.3%, $P < 0.001$)) but in the non-appendicitis group, the most common complaint was abdominal pain (56.0%, $P = 0.012$). We collected the maximal point of tenderness of each patient, also described in **Table 3**, and found that the maximal point of tenderness at RLQ was significantly higher in acute appendicitis patients ($P = 0.002$). We analyzed clinical presentations and initial investigations of our patients including onset of symptoms, migratory pain, fever (> 38 ºC), nausea/vomiting, RLQ tenderness, maximal point of tenderness, white blood cell counts, neutrophil counts (%), and pediatric appendicitis score. The data was shown in **Table 4**. Among these factors, multi-variate analysis using logistic regression demonstrated that migratory pain, RLQ tenderness, higher white blood cell counts, and higher percentage of neutrophils were significantly independently associated with appendicitis.

Table 3. Baseline characteristics of patients with abdominal pain consulted for surgical evaluation.

	Appendicitis (n = 41)	Non-appendicitis (n = 50)	*P* - value
Demographic characteristics			
Gender (male)	23 (56.1%)	21 (42.0%)	0.181
Age (years)	10.2 (8.6 - 11.9)	9.3 (6.3 - 12.6)	0.359
Weight (kg)	38.6 (23.5 - 51.4)	32.4 (18.1 - 45.3)	0.62
Weight for age (Z-score)	0.4 (-0.6 - 1.4)	0.1 (-1.0 - 1.3)	0.76
Clinical complaints			
Abdominal pain	12 (29.3%)	28 (56.0%)	0.012
Migratory pain	19 (46.3%)	2 (4.0%)	< 0.001
Right lower quadrant pain	9 (22.0%)	15 (30.0%)	0.476
Others	1 (2.4%)	5 (10.0%)	0.217
Maximal point of tenderness			
Epigastrium	0 (0%)	2 (4.0%)	0.499
Generalized	1 (2.4%)	4 (8.0%)	0.246
Lower abdomen	4 (9.8%)	4 (8.0%)	0.768
Right periumbilical	1 (2.4%)	14 (28.0%)	0.0012
Left lower quadrant	0 (0.0%)	2 (4.0%)	0.499
Right lower quadrant	35 (85.4%)	24 (48.0%)	0.002

Table 4. Factors distinguishing patients with appendicitis from patients with non-appendicitis (using logistic regression analysis).

	Appendicitis (n = 41)	Non-appendicitis (n = 50)	*P* - value
Onset of symptoms (median, hours)	24 (10.0 - 48.0)	24 (5.8 - 48.0)	0.976
Migratory pain	19 (46.3%)	5 (10.0%)	< 0.001
Fever	14 (34.1%)	15 (30.0%)	0.673
Nausea/Emesis	27 (65.9%)	30 (60.0%)	0.566
RLQ tenderness	38 (92.7%)	36 (72.0%)	0.012
White blood cell counts ($x10^3$)	16.4 (12.7 - 19.8)	12.4 (9.4 - 14.9)	0.001
Neutrophil counts (≥ 75%)	83.3 (76.0 - 87.0)	74.8 (61.5 - 81.8)	0.001
Pediatric appendicitis score	6 (5.0 - 7.0)	4 (3.0 - 5.0)	< 0.001

Acute appendicitis in special groups; patients younger than 5 years old and obese patients

For children younger than five years old, there were 10 patients (10/91 or 11.0%) who were younger than 60 months old (< 5 years old) in this study. All of them were managed according to this practice guideline. There were two children diagnosed with acute appendicitis. One was diagnosed with clinical acumen, and the other was diagnosed by ultrasonography of the abdomen. No patient in this group was either misdiagnosed or delayed in treatment.

For obese patients, obesity was defined by BMI more than the 95th percentile. There were 15 obese patients (15/91 or 16.5%) included in this study. Only one patient needed a CT scan for a definitive diagnosis.

Complicated appendicitis

Perforated appendicitis, appendiceal phlegmon, gangrenous appendicitis, and appendiceal abscess are classified as complicated appendicitis in this study. There were 14 patients with complicated appendicitis in this cohort (14/41 or 34.1%). None of the patients required a CT scan for diagnosis. Two patients were partially treated with antibiotics. In addition, six patients with complicated conditions were obese (6/14 or 42.9%).

Discussion

Although acute appendicitis is the most common pediatric surgical consultation, there are still some arguments about appropriate evaluations of the disease. Evaluation strategies rely on available resources in each institute. Despite differences, every practice should go along with an appropriate standard of care. This study represented our current management, and it showed that nearly half of the consultation cases could be managed by clinical acumen alone with 2.4% of negative appendectomy. In equivocal presentations, the chosen modalities depended on attending physicians and clinical suspicion. Patients with serious illnesses such as septic shock or patients with complicated underlying diseases were usually instantly requested for a CT scan. We excluded this group of patients due to severe medical conditions.

The diagnostic accuracy of ultrasound varies among institutes due to facilities and operator factors. [11] According to a meta-analysis study of 26 studies, Doria AS, *et al*. [12] reported pooled sensitivity and specificity for ultrasound diagnosing pediatric appendicitis of 88.0% and 94.0% respectively, while our study showed a sensitivity of 78.6% and a specificity of 96.6%. However, a wide range of this diagnostic modality was observed which were 44.0% to 88.0% in sensitivity and 90.0% to 97.0% in specificity. The accuracy of ultrasound may vary not only because of operators but also patient factors including obesity [13 - 15] and the location of the appendix, retrocecal in particular. [15]

Recent data revealed a higher rate of pediatric patients receiving a CT scan in order to search for appendicitis. Higher odds are observed especially in hospitals with a low volume of pediatric patients. [16 - 18] As it occurs in most general hospitals, they do not have radiologists available for performing ultrasonography during off-hours. Therefore, the proportions are likely to be different between our hospital and others. Since we exclude patients who were diagnosed and underwent CT scans before referring to our institute and patients with serious medical conditions, there were only six patients in an equivocal presentation group performing CT (12.0%).

Demographic data between patients diagnosed with clinical acumen and those with equivocal presentation were not different. We found three factors that distinguish these two groups: migratory pain, percentage of neutrophils, and calculated pediatric appendicitis score (PAS). Patients with obvious clinical acumen tended to have higher PAS and did not need further investigation, while others might need further management to rule out surgical diseases. Our study found that some patients with low PAS (1 - 3) were diagnosed with acute appendicitis and confirmed by pathological reports. This emphasizes that appropriate follow-up should be advocated in order to reduce delayed diagnosis cases leading to morbidity and mortality. [19] As it appears in Rich BS, *et al.* study. [20] regarding malpractice in pediatric surgical conditions, appendicitis accounts for the most common disease involving a delay in diagnosis and mortality cases. Since the accuracy of diagnosing appendicitis using our institution's practice is 94.5% with low rate of CT scan utilization, we propose the guideline for the management of children with suspected appendicitis as shown in **Figure 4.**

Although the results of our study seem to be clinically applicable, it has some limitations. Firstly, this is a retrospective review which has some missing details. Secondly, ultrasound performance is lower than previous literature. This tends to originate from available radiologists based on period of consultation. For example, during working-hour ultrasonography is mostly performed by pediatric radiologists, while all ultrasound cases in an off-hour period are done by radiological residents. Moreover, we represent management in a single tertiary hospital that has access to 24 hour ultrasonography, which is not available at many hospitals. Therefore, the rate of CT scans at our institute is much lower compared to other hospitals.

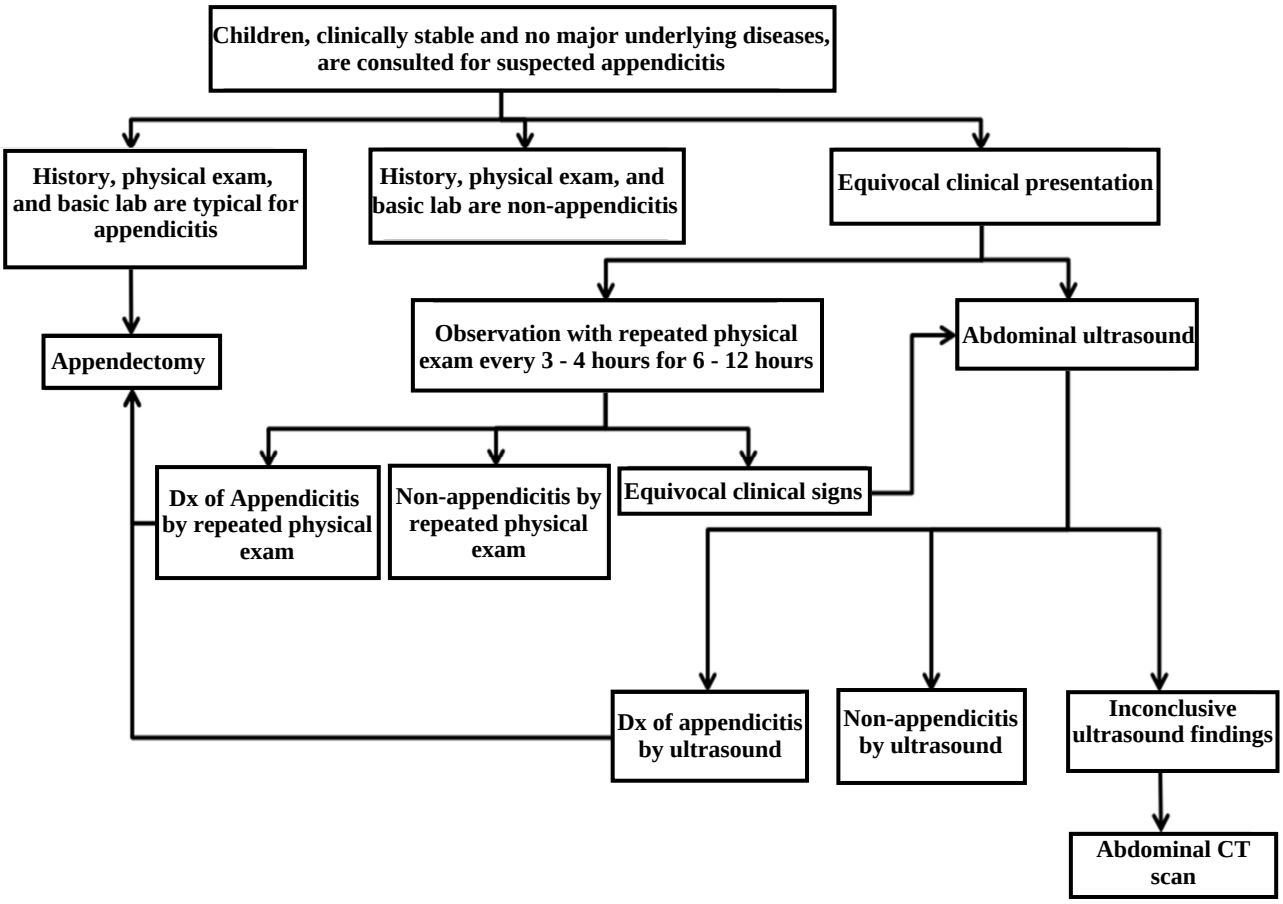

Figure 4. Proposed management guideline for children with suspected appendicitis.

Conclusions

Acute appendicitis is a common surgical disease by which physicians still search for safe, accurate, and efficient diagnoses. By minimizing CT utilization, our management achieved rather high predictive value and there was neither misdiagnosis nor delayed diagnosis during our study period. In order to increase accuracy in management, ultrasonography is preferable effective imaging modality in our setting that helps diagnose patients with equivocal presentation. However, CT scan is beneficial for patients with worsen symptoms and inconclusive ultrasound. Most importantly, careful history taking, detailed physical examination and complete blood counts were still pivotal keys for differentiating patients with appendicitis from those with non-appendicitis. Logistic regression demonstrated that migratory pain, RLQ tenderness, elevated white blood cell counts, and high proportion of neutrophils were independently associated with appendicitis.

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Conflicts of interest statement

Each of the authors has completed an ICMJE disclosure form. None of the authors declare any potential or actual relationship, activity, or interest related to the content of this article.

Data sharing statement

The present review is based on the references cited. Further details, opinions, and interpretation are available from the corresponding authors on reasonable request

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