



## Original Article

# Integration of ultrasound findings with Alvarado score in children with suspected appendicitis

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**Abstract** **Background:** The aim of this study was to investigate the integration of ultrasound (US) findings with Alvarado score in diagnosing or excluding acute appendicitis.

**Methods:** Data were analyzed in 122 pediatric patients with suspected appendicitis who had undergone US. The US findings were classified into four groups, and the patients were classified into three groups according to Alvarado score. US results and Alvarado score were compared.

**Results:** Alvarado score was a good predictor of appendicitis for scores  $\geq 7$ .

**Conclusion:** In the case of non-visualization of the appendix without a high Alvarado score, appendicitis can be safely ruled out.

**Key words** Alvarado score, appendicitis, pediatric, ultrasound.

Acute appendicitis is the most common cause of abdominal surgical emergency.<sup>1,2</sup> Acute appendicitis remains a clinical diagnosis, but when clinical diagnosis of appendicitis is difficult, ultrasound (US) has been proved to be a helpful imaging modality in patient evaluation, especially in children with suspicion of appendicitis.<sup>3,4</sup> Methods advocated to assist in the diagnosis of appendicitis other than US include laparoscopy,<sup>5,6</sup> scoring systems,<sup>7,8</sup> computed tomography (CT)<sup>9</sup> and magnetic resonance imaging (MRI).<sup>10</sup> Graded compression US is the least expensive and least invasive method and has been reported to have an accuracy of 70–95%.<sup>11–15</sup> US findings in the diagnosis of acute appendicitis have historically been divided into three groups: negative for appendicitis; equivocal findings; and acute appendicitis.<sup>16</sup>

The Alvarado score is a 10 point scoring system for the diagnosis of appendicitis based on clinical signs and symptoms and a differential leukocyte count (Table 1).<sup>17</sup> Prospective studies have suggested that the Alvarado score alone is inadequate as a diagnostic test.<sup>18,19</sup> Normal appendix vermiformis may be visualized on sonography. In the literature, the rates of visualization of normal appendix vary between 2% and 82%.<sup>20–23</sup> In the absence of visualization of normal appendix vermiformis or inflamed appendix on sonography, CT can be used for diagnosing appendicitis. Overall, the sensitivity and specificity of CT in diagnosing appendicitis is higher than US in the literature.<sup>13,14,24</sup> Due to the long-term risk of ionizing radiation, however, CT should not be

the preferred imaging method, especially in children. In the absence of visualization of normal appendix vermiformis or inflamed appendix on sonography, a combination of Alvarado score and US findings might be of use in splitting this group into a negative or positive diagnosis of acute appendicitis. In the present study, we devised a new integrated classification of the results of abdominal US with Alvarado score (low, moderate, high) in diagnosing or excluding acute appendicitis. Therefore, the purpose of this study was to evaluate the integration of US findings with Alvarado score in children with suspected appendicitis.

## Methods

From January 2011 to July 2011, 122 children with acute abdominal pain (acute onset, <3 days) who were clinically suspected of having appendicitis and referred by the resident of pediatrics or the pediatric surgeon to the department of radiology for abdominal US were included in the present retrospective study. The subject group ( $n = 122$ ) included 63 boys and 59 girls with a mean age of 11 years (age range, 2–15 years). Informed consent was obtained from the children's parents. Institutional review board approval was obtained for the present study.

The abdomen was examined using a Logic P9 US system (Logic PG; GE Healthcare, Wauwatosa, WI, USA). The entire abdomen was examined with a 4 MHz curved-array transducer, and the right lower quadrant of the abdomen with a 10 MHz linear-array transducer. US examinations were performed two experienced radiologist (H.T. with 10 years experience in abdominal US; and I.C.A. with 5 years experience in abdominal US). All abdominal organs were examined using graded compression of the right lower quadrant according to the

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**Table 1** Calculation of Alvarado score

Symptoms	Score
Migratory right iliac fossa pain	1
Nausea/vomiting	1
Anorexia	1
Signs	
Tenderness in right iliac fossa	2
Rebound tenderness in right iliac fossa	1
Elevated temperature	1
Laboratory findings	
Leukocytosis	2
Shift to the left of neutrophils	1
Total	10

recommendations of Puylaert.<sup>25</sup> Radiologists had no information on the patients' Alvarado scores. The examiner classified the results of abdominal US in four groups: group 1, normal appendix (diameter < 6 mm) visualized; group 2, appendix not visualized without secondary signs of appendicitis; group 3, appendix not visualized but one or more of the secondary signs of appendicitis were present; group 4, appendicitis with visualization of an inflamed appendix or perforated appendicitis. Criteria for the US diagnosis of inflamed appendix included identification of the appendix as a fluid-filled, non-compressible, blind-ended tubular structure with a diameter  $\geq$  6 mm.<sup>26</sup> Secondary signs of appendicitis were increased echogenicity of the surrounding mesenteric fat, local fluid collection suggesting an appendicular abscess, or local dilatation of the bowel without peristalsis, indicating focal peritonitis. Sonographic features of perforated appendicitis were target sign and tubular structure with inhomogeneous structure and/or missing layers in the wall and/or absent peristalsis. Alternative diagnoses found in group 1 or 2 patients during US were also recorded. We accepted a US diagnosis of negative for patients in groups 1 and 2. In groups 3 and 4, US diagnosis was

positive for acute appendicitis. After US was performed, the pediatric surgeon calculated the Alvarado scores and classified the patients into three groups according to Alvarado score: (i) low Alvarado score (Alvarado score  $\leq$  4); (ii) moderate Alvarado score (Alvarado score 5,6); (iii) high Alvarado score (Alvarado score  $\geq$  7).

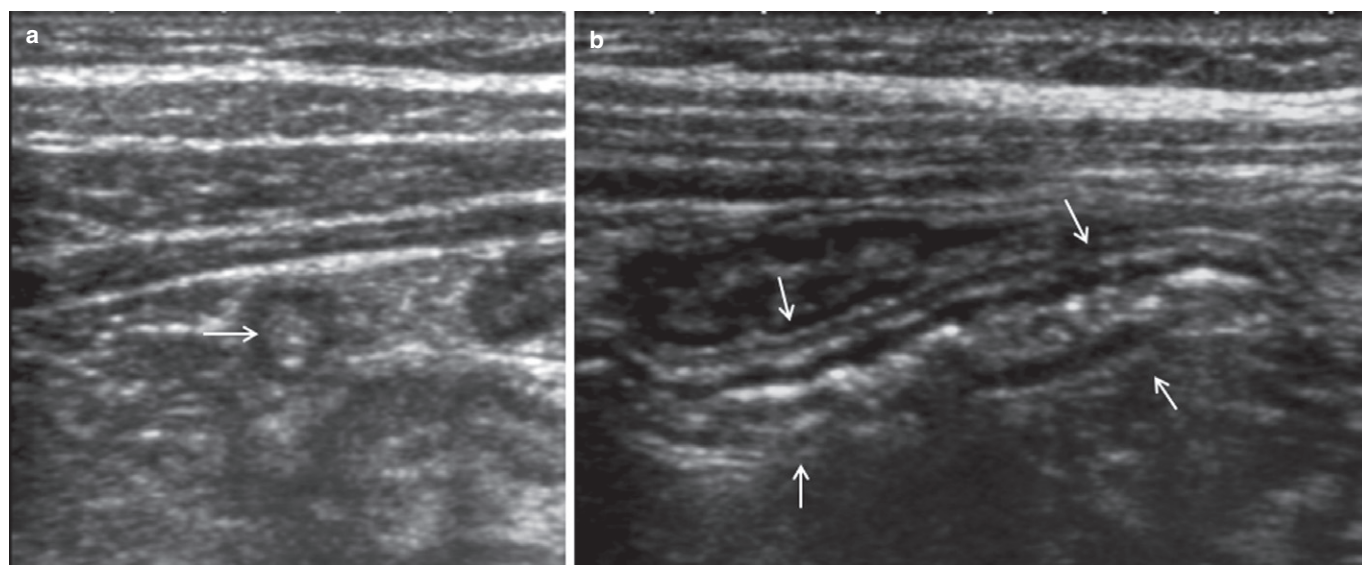
Almost all patients in US groups 3 and 4 were treated surgically. If the Alvarado score was  $\geq$  7 (Alvarado group 3), patients underwent surgical operation due to high clinical suspicion of appendicitis. Decision to operate was dependent on clinical findings.

Perforation of the appendix noted at surgery and/or pathology results were also recorded. Clinical data were reviewed for all patients (operated or not operated) via re-evaluation appointments at the outpatient clinic or by phone monthly. Complications (i.e. missed appendicitis or postoperative complications) and recurrence of a new episode of abdominal complaint diagnosed as appendicitis within 3 months after the first visit, were noted. If we could not contact the patients, these patients were not included in the study.

## Results

The prevalence of appendicitis, confirmed on surgery and/or pathology, in the present study was 47.5% (58/122). A normal appendix was seen in 15 (12%) of 122 patients, all of whom were in US group 1 (Fig. 1). Patients in US group 1 (all with low Alvarado score) were given expectant treatment or conservative treatment for the alternative diagnosis found on US examination.

Ultrasound group 2 ( $n = 48$  patients) consisted of all the patients whose appendix could not be visualized in the absence of secondary signs of appendicitis. Patients in US group 2 were given expectant treatment or conservative treatment for the alternative diagnosis found on US examination if their Alvarado scores were  $< 7$ . If the Alvarado score was  $\geq 7$ , patients underwent



**Fig 1** Ultrasound image showing (a) transverse and (b) longitudinal section of a normal appendix (white arrows). The patient was included in group 1.

surgical operation due to high clinical suspicion of appendicitis. Four patients in US group 2 (false-negative cases) underwent operation because of high clinical suspicion of acute appendicitis and appendicitis proven on pathology. These four patients had an Alvarado score  $\geq 8$ .

Patients in US groups 3 and 4 (except five patients with low and moderate Alvarado scores in US group 4) were treated surgically. There were only two patients in US group 3. In both of them, hyperechoic mesenteric fat and fluid collection were present as secondary signs of appendicitis. US group 4 contained 57 patients (47%) who met the US criteria of acute appendicitis. The diagnosis was false positive for five patients in US group 4. These five patients had Alvarado score  $\leq 6$  and were clinically followed. The symptoms of these patients were relieved with conservative treatment (oral wide-spectrum antibiotics) and discharged from hospital. In the other 52 patients, in whom inflamed appendicitis was visualized on US, appendicitis was confirmed on surgery and pathology (true-positive cases). The US diagnosis of acute appendicitis was true positive in 54 patients (including two patients in US group 3), false positive in five patients (US group 4), false negative in four patients (US group 2), and true negative in 59 patients. The diagnostic accuracy of US for the clinical diagnosis of acute appendicitis was as follows: sensitivity, 93.1% (54/58); specificity, 92.2% (59/64); positive predictive value, 91.5% (54/59); negative predictive value, 93.6% (59/63); and accuracy, 92.6% (113/122).

Alvarado scores and final diagnoses according to US group are listed in Table 2. All the patients in US group 1 had Alvarado score  $< 5$ . In US group 2, four patients (false-negative cases) had a high Alvarado score, underwent surgery, and appendicitis was proven surgically and pathologically. In US groups 3 and 4, four patients had a moderate Alvarado score, two patients had a low Alvarado score and only one patient (Alvarado score, 6) underwent surgery due to lack of response to conservative treatment, and appendicitis was proven surgically and pathologically. In the other three patients, Alvarado score was 6, but they had a good response to conservative treatment and their symptoms were relieved without an operation.

The mean Alvarado score was 6.5. There were 41 patients in Alvarado score group 1 (low Alvarado score). There were two patients in Alvarado score group 1 (low Alvarado score) and four patients in Alvarado score group 2 (moderate Alvarado score)

who had a diagnosis of acute appendicitis on US, but only one of them underwent operation and appendicitis was proven by surgery and pathology; the others were clinically followed (sonographically false-positive cases). In all patients with high Alvarado score (Alvarado group 3), sonographically normal appendix vermiformis could not be demonstrated. In this patient group, four patients were in US group 2 and 53 patients were in US groups 3 and 4. All the patients in Alvarado score group 3 underwent operation, and appendicitis was proven by surgery and pathology. Alvarado score was a good predictor of appendicitis if the score was  $\geq 7$  (% 100 predictive value).

In 13 cases, the appendix was perforated; the total perforation rate was 11%. The perforation rate was 6% (3/48) in US group 2, 100% (2/2) in US group 3 and 14% (8/57) in US group 4.

## Discussion

Diagnostic imaging of the appendix has improved steadily over the past decade. US has been used traditionally as the primary imaging method in children because it uses no ionizing radiation, is relatively easy and quick to perform, and is well-tolerated by children.<sup>4,27–30</sup> US instills less confidence in the situation of non-visualization of normal or inflamed appendix, and management strategies are rarely based on negative sonographic findings. In such a situation, laparoscopy, scoring systems, CT and MRI can be used in the diagnosis of acute appendicitis.

We have confirmed the high sensitivity, specificity and accuracy (sensitivity, 93%; specificity, 92%; accuracy, 92%) of graded compression US in the diagnosis of appendicitis. Although the overall accuracy of sonography in the diagnosis of acute appendicitis is very high, there are some problems and limitations of US that can produce false-positive and false-negative results. In the present study, in 48/122 cases, normal or inflamed appendix was not visualized, in four of which, appendicitis was surgically proven. Similar experiences have been reported by other authors.<sup>31–36</sup> Other reasons for false-negative results are problems of measurement especially in a focal appendicitis.<sup>37–39</sup> If the non-inflamed part of the appendix is measured, especially the proximal part, the appendicitis may be overlooked.<sup>4,28,40–43</sup> To minimize this error, it is important to visualize the appendix in the longitudinal and transverse planes. In the present study there were five false-positive US results. There are diseases known to give the appendix an abnormal appearance: lymphoid hyperplasia<sup>12,44</sup> and

**Table 2** Alvarado score and final diagnosis vs US group

US group	No. patients <i>n</i> (%)	Alvarado score group 1 (low: $\leq 4$ )	Alvarado score group 2 (moderate: 5,6)	Alvarado score group 3 (high: $\geq 7$ )	Final diagnosis
1	15 (12)	8	7	0	No operation
2	48 (39)	31	13	4	Only four patients with high Alvarado score underwent operation, and acute appendicitis was proven pathologically.
3 and 4	59 (49)	2	4	53	A total of 54 patients underwent operation. One patient with moderate Alvarado score and 53 patients with high Alvarado score underwent operation. Appendicitis was proven pathologically.
Total	122	41	24	57	58



cystic fibrosis. Another possible trap in diagnosing acute appendicitis with US is the occurrence of spontaneously resolving appendicitis.<sup>44,45</sup> Some diseases, such as Crohn's disease and peritonitis, may also mimic acute appendicitis sonographically in the case of non-visualization appendix, by creating secondary signs.<sup>16</sup>

Alvarado score is a well-tested and widely published 10-point clinical scoring system.<sup>46</sup> In prospective studies it has been proposed that Alvarado score on its own was insufficient as a diagnostic test.<sup>18,19</sup> We used Alvarado score combined with US findings as an objective means of stratifying patients according to risk in order to identify those with a high or low probability of appendicitis. In the present study, Alvarado score was a good predictor of appendicitis for a score cut-off of 6. All the patients with Alvarado score  $\geq 7$  had a diagnosis of acute appendicitis. The present data suggest that if Alvarado score is  $>6$  and inflamed appendix cannot be visualized on US, then surgery is the appropriate treatment modality without further imaging method, especially CT. The present data also suggest that if the patient has a moderate Alvarado score (i.e. Alvarado score 5,6) and US could not visualize inflamed or normal appendix, then CT should be considered in spite of the radiation risk, because there would be false-negative and -positive cases. Besides the radiation risk, CT is also less desirable in children because of their lack of abdominal fat, which leads to difficulty in recognition of fat stranding. But if the patient is obese, which is a limiting factor in the use of US, further evaluation with CT may be considered. CT, in contrast to US, is more expensive, more invasive, with the use of oral, i.v. or rectal contrast, and requires sedation in some children.

This study was limited by the lack of pathological proof in those patients for whom no appendectomy was performed. We considered the results as true negative when the patient complaints resolved at re-evaluation in the outpatient clinic or if patients did not go to another hospital during follow up and/or had a successful response to conservative treatment of an alternative diagnosis. We excluded the patients who could not undergo re-evaluation or who could not be reached by phone. This was another limitation of the present study.

## Conclusion

In the case of non-visualization of the appendix without a high Alvarado score, appendicitis can be safely ruled out. CT may be useful in children with moderate scores and equivocal US findings.

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