ORIGINAL ARTICLE

Alvarado scores and pain onset in relation to multislice CT findings in acute appendicitis

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PURPOSE
To determine the correlation between clinical and multislice computed tomography (MSCT) findings of early- and late-stage acute appendicitis.

MATERIALS AND METHODS
The study was conducted between June 2003 and February 2006 with 143 patients. Patients were divided into 3 groups according to Alvarado scores: group 1 (n = 18; 13%; score: 1-4), group 2 (n = 70; 49%; score: 5-7), and group 3 (n = 55; 38%; score: 8-10). Abdominal MSCT results were compared to histopathological diagnoses. Patients were then divided into 2 other groups according to pain onset (MSCT performed within the first 12 h of pain onset and MSCT performed thereafter).

RESULTS
Histopathological findings were normal in 13 of the 143 patients (9%). The positive predictive value of MSCT did not significantly differ between the 3 Alvarado groups (92.8% in group 1, 95.1% in group 2, and 98.0% in group 3). Additionally, the positive predictive value of MSCT did not differ whether the scans were performed within the first 12 h of pain onset or thereafter (88% and 89%, respectively; $P = 0.89$).

CONCLUSION
MSCT should be performed even in patients in whom the clinical suspicion of appendicitis is low. MSCT is effective in patients with early-stage appendicitis.

Key words: • acute appendicitis • multislice computed tomography

In developed countries acute appendicitis is the most common cause of acute abdominal pain requiring surgical intervention (1, 2). Acute appendicitis is diagnosed with clinical accuracy in 80% of patients (2, 3). Computed tomography (CT) has emerged as the dominant imaging modality for evaluating adults with suspected appendicitis. Regardless of the technique used, the reported accuracy in diagnosing appendicitis ranges from 90% to 99%. The sensitivity of CT ranges from 87% to 100%, and its specificity ranges from 83% to 100% (4–8). About one third of patients with acute appendicitis have atypical clinical signs, symptoms, and laboratory findings (9).

Prior to CT and ultrasonography (US), various clinical scoring systems were used for diagnosing appendicitis, depending on medical history, as well as the results of physical examination and laboratory testing. The Alvarado score is a 10-point clinical scoring system that has been well tested and widely published (2). In his original paper, Alvarado recommended surgery for all patients with a score ≥7 and observation for patients with scores of 5 or 6 (10). Subsequent prospective studies suggested that the Alvarado score alone is inadequate as a diagnostic test (11, 12). Nevertheless, it has been recommended for selecting patients who should undergo imaging (13). The components of the Alvarado scoring system are migratory right iliac fossa pain, anorexia, nausea and vomiting, tenderness in the right iliac fossa, rebound pain, elevated temperature, leucocyte count, and differential white cell count with neutrophils (Table 1).

The purpose of any clinical scoring system or imaging method in suspected acute appendicitis (or abdominal pain) is to correctly determine the etiology/disease in order to administer the appropriate treatment. Clinical scoring (Alvarado score or any other score) needs to be supported by imaging modalities (CT, US, abdominal X-ray, etc.) in order to achieve this goal.

In cases of acute appendicitis, it is important to obtain an early correct diagnosis before complications occur. Another important issue is decreasing the negative appendectomy rate (the prevalence of surgical excision of normal appendixes should be reduced without increasing the perforation rate). In most institutions, CT imaging is performed, especially in patients with atypical clinical presentation. For this reason, abdominal surgeons most frequently request CT for patients with an intermediate Alvarado score (5-7). The Alvarado score is a useful tool for diagnosing acute appendicitis, particularly for the scores at both ends of the scale.

The purpose of this study was to compare the sensitivity and specificity of multislice CT (MSCT) to the Alvarado score. We also evaluated whether the interval between pain onset and the time MSCT was performed affected the sensitivity and specificity of MSCT results.

Materials and methods

The study included 143 consecutive patients (78 men, 65 women; mean age: 34 years; range: 18–76 years) with abdominal pain that presented to our emergency department between June 2003 and February 2006. Abdominal US (Philips, HDI 5000, The Netherlands) examinations of all patients were negative for acute appendicitis or were suboptimal due to obesity and intestinal gas distension. Each patient's medical history, physical examination and, laboratory test findings, and Alvarado score were recorded. We divided the study population into 3 groups based on the Alvarado score as follows: group 1 (n = 18; 13%; score 1-4, low likelihood of appendicitis), group 2 (n = 70; 49%; score 5-7, probable appendicitis), and group 3 (n = 55; 38%; score 8-10, strong likelihood of appendicitis).

Abdominal MSCT was performed at 120 kV, 124 mAs, 6.5-mm slice thickness, and with collimation (Philips, MX 8000, The Netherlands). The abdomen and pelvis were scanned during the portal venous phase after a dynamic bolus of 150 ml of iohexol (Omnipaque 300, Amersham Health), a non-ionic contrast material, was administered intravenously with a power injector at the rate of 3 ml/s. Total examination time was 10 min. In total, 98 patients received approximately 50 ml of an oral ionic contrast medium (Telebrix®, Guerbet, France) in 2500 ml of water 2 h prior to scanning. The remaining 45 patients did not tolerate oral contrast material and MSCT was performed only with intravenous non-ionic contrast material. Although focused MSCT imaging of the appendiceal region performed without contrast material (IV or oral) is equally successful in diagnosing acute appendicitis, we don't prefer this protocol. We think the use of oral and intravenous contrast material is very helpful in determining other possible abdominal conditions that have clinical findings similar to acute appendicitis.

Radiologists, who were blinded to the clinical and laboratory results, interpreted the MSCT images. The MSCT criteria for appendicitis were visualization of the appendix, increased diameter of the appendix (>7 mm), the presence of right lower quadrant inflammatory stranding, a thickened appendiceal wall (>3 mm), appendiceal wall enhancement, the presence of right lower quadrant or pelvic fluid, and the presence of an appendicolith. MSCT findings were compared to the histopathological results of the 3 groups (Fig. 1, 2).

Statistical analyses were performed with SPSS v.9.0 (Statistical Package for the Social Sciences, SSPS Inc, Chicago, IL, USA). The t-test was used to compare the groups in pairs for all possible combinations. Numeric values are expressed as means ± SD and categorical variables are presented as percentages. Chi-square analysis was used to compare the groups for categorical variables. One-way analysis of variance (ANOVA) was used to compare the 3 Alvarado scoring groups. A P value <0.05 was regarded as statistically significant. The receiver operating characteristic (ROC) curve was used to evaluate the predictive performance of CT in detecting acute appendicitis. The area under the ROC curve and its standard error were calculated. The sensitivity, specificity, and positive and negative predictive values of CT were calculated individually for each 3 groups.

In order to compare the diagnostic accuracy of CT in early appendicitis, patients were divided into 2 other groups: CT performed within first the 12 h of pain onset and CT performed >12 h after pain onset. Usually, most patients have somatic pain first, which becomes visceral pain within 1–12 h (14). The sensitivity, specificity, and positive and negative predictive values of CT were calculated separately for these 2 groups.

Results

Histopathological findings were normal in 13 of the 143 patients (9%). The positive predictive value of CT did not significantly differ between the 3 Alvarado groups (92.8% in group 1, 95.1% in group 2, and 98.0% in group 3).

According to the Alvarado scores, 18 of the 143 patients were included in group 1. Of those 18 patients, 14 (77.7%) were diagnosed with appendicitis and 4 (22.2%) were not diagnosed with appendicitis based on MSCT exams. In group 1, the diagnosis of appendicitis was proven with histopathological analysis in 13 patients, and histopathological results were normal for 1 patient. Normal histopathological findings were found in 2 of 4 patients whose MSCT results were interpreted as negative for appendicitis. The sensitivity and specificity of MSCT were 86.6% and 66.6%, respectively (Table 2).

Of the 143 patients, 70 were included in group 2. Of those 70 patients, 62 (88.5%) were diagnosed with appendicitis and 8 (11.4%) were not diagnosed with appendicitis. Appendicitis was confirmed by histopathological analysis in 59 patients and 3 patients had normal histopathological results. Histopathological findings were normal in 4 of 8 patients that were not diagnosed with appendicitis based on MSCT exams. The sensitivity and specificity of MSCT were found to be 93.6% and 57.1%, respectively (Table 2).

Of the 143 patients, 55 were included in group 3. Of those 55 patients, 51 (92.7%) were diagnosed with appendicitis and 4 (7.2%) were not diagnosed with appendicitis based on MSCT ex-
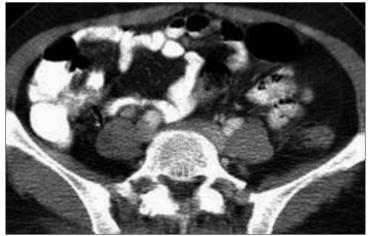
Table 1. Components of the Alvarado score

Clinical findings	Score
Migration of pain	1
Anorexia	1
Nausea/vomiting	1
Tenderness in right iliac fossa	2
Rebound pain	1
Elevated temperature (> 37.3 °C)	1
Leucocyte count $\geq 10 \times 10^9$/L	2
Differential white cell count with neutrophils > 75%	1
Total	10

Figure 1. Axial contrast enhanced MSCT image of a 45-year-old woman (group 1). Note the normal appendix with intraluminal air. Histopathological diagnosis was focal appendicitis.
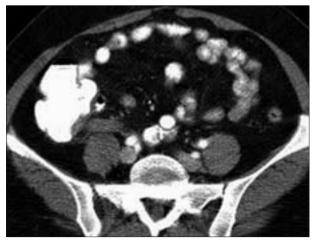

Figure 2. Axial MSCT image of a 47-year-old woman (group 2) after oral and IV contrast administration shows thickened appendiceal wall and swollen appendix. Histopathological diagnosis was appendicitis.

ams. The diagnosis of appendicitis was confirmed by histopathological analysis in 50 patients and 1 patient had normal histopathological findings. Histopathologic findings were normal in 2 patients whose MSCT examinations revealed no sign of appendicitis. The sensitivity and specificity of MSCT were 96.1% and 66.6%, respectively (Table 2).

Despite the relatively high diagnostic rate of MSCT, false-positive and false-negative MSCT rates (4.5% and 6.8%, respectively) were higher in groups 1 and 2 than they were in group 3 (1.8% and 3.6%, respectively). There were 5 patients (3 female, 2 male) with a false-positive MSCT result. The actual diagnoses were pelvic inflammation in 2 female patients, colitis in 1 male patient, peri-appendicitis in 1 female patient, and the other male patient had no alternative diagnosis after surgery.

The positive predictive value of MSCT did not differ whether the scans were performed within the first 12 h of pain onset or thereafter (88% vs. 89%; $P = 0.89$). The sensitivity and specificity of MSCT scans within the first 12 h of pain onset were 92.1% and 66.6%, respectively. When scanning was performed ≥12 h after pain onset, the sensitivity and specificity of MSCT were 94.5% and 60%, respectively (Table 3).

In addition, the study population was divided into 2 groups according to whether or not MSCT findings demonstrated appendicitis: MSCT (+) group (n = 127) and MSCT (-) group (n = 16). Although only 5 of 127 patients (4%)

in the MSCT (+) group had normal histopathological findings, 8 of the 16 patients (50%) in the MSCT (–) group had normal histopathological findings ($P < 0.001$). We also demonstrated that MSCT was a good predictor of acute appendicitis based on the ROC curve. The

area under the ROC curve was 78% (95% confidence interval, 0.62–0.94) and MSCT had significant predictive value in diagnosing acute appendicitis ($P = 0.001$) (Fig. 3).

Table 2. CT results of the 3 Alvarado groups

	Diagnosis of CT								
	True (+)	True (-)	False (+)	False (-)	Sensitivity (%)	Specificity (%)	Accuracy (%)	PPV (%)	NPV (%)
Group 1 n = 18	13	2	1	2	86.6	66.6	83.3	92.8	50.0
Group 2 n =70	59	4	3	4	93.6	57.1	90.0	95.1	50.0
Group 3 n = 55	50	2	1	2	96.1	66.6	94.5	98.0	50.0

PPV: positive predictive value; NPV: negative predictive value.

Table 3. Time-dependent CT results

	Group 1 (≤12 h of pain onset) (n = 41)	Group 2 (>12 h of pain onset) (n = 102)
Sensitivity (%)	92.1	94.5
Specificity (%)	66.6	60.0
Accuracy (%)	90.2	91.1
PPV (%)	97.2	95.6
NPV (%)	40.0	54.5

PPV: positive predictive value; NPV: negative predictive value.
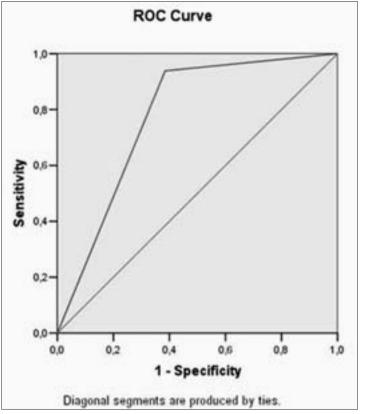
Figure 3. Receiver operating characteristic (ROC) curve analysis. The sensitivity and specificity of CT was high for the diagnosis of acute appendicitis.

Discussion

Abdominal CT is a well-established radiological modality for diagnosing and differentiating appendicitis. Many studies have shown that CT is highly accurate in evaluating acute appendicitis, although which technique is optimal remains controversial (6–8). Helical CT has a reported sensitivity of 90%–100%, a specificity of 91%–99%, an accuracy of 94%–98%, a positive predictive value of 92%–98%, and a negative predictive value of 95%–100% in diagnosing acute appendicitis (6–8). About 33% of patients with acute appendicitis have atypical presentation (9). Furthermore, patients with other abdominal conditions may present with clinical findings similar to those caused by acute appendicitis (15). Thus, although appendicitis has traditionally been a clinical diagnosis, many patients undergo unnecessary surgery. The misdiagnosis of this acute condition has led to unnecessary laparotomy in 8%–30% of patients (8). A negative appendectomy rate as high as 20% has been considered acceptable in the lit-

erature (16, 17); however, unnecessary laparotomy can be avoided in many patients if modern diagnostic methods are used to confirm or exclude acute appendicitis.

Various clinical scoring systems are used, depending on patient's medical history and the results of physical examination and laboratory testing. The Alvarado scoring system has been well tested and published (2). Garfield et al. (18) reported that clinical findings (i.e., the Alvarado score) did not correlate with the choice to use advanced radiography. Similarly, Winn et al. (19) reported that using the Alvarado score and selective outpatient management with antibiotics is simple and requires no imaging. They reported that patients with a low clinical score (Alvarado group 1) required no treatment and that perforation occurred in only 5% of group 2 patients. In addition, Douglas et al. (20) reported that patients with an Alvarado score ≤4 (Alvarado group 1) did not have appendicitis that required surgical treatment.

In the present study there was no statistically significant correlation between MSCT results and Alvarado scores, either. However, this does not indicate that MSCT is not a useful imaging modality in diagnosing acute appendicitis, and it does not mean that there is no need to use advanced radiology (i.e. US or CT) or to follow-up these patients, as in our study in which histopathologically proven acute appendicitis was diagnosed in 13 of 18 patients (72.2%) in group 1. Although the sensitivity and diagnostic accuracy of MSCT were lower in patients with low Alvarado scores than the other patients in the study, use of advanced radiology in these patients that did not arouse clinical suspicion might prevent the occurrence of complications such as perforation.

In addition, we found that the sensitivity, specificity, accuracy, and positive and negative predictive values of MSCT did not differ with the duration of pain. This means that MSCT is very effective in diagnosing early appendicitis.

The major limitation of our study is the small number of patients, especially in Alvarado group 1. Further studies with larger series should be conducted.

In conclusion, because most of the patients with an Alvarado score ≤4 had acute appendicitis, CT should be performed in all patients, even when there is low clinical suspicion, and no patient with a low score should be safely sent home. In addition, the diagnostic accuracy of MSCT is independent of the time of pain onset and MSCT is effective in patients with early-stage appendicitis.

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