Am J Nucl Med Mol Imaging 2023;13(1):11-17
www.ajnmmi.us /ISSN:2160-8407/ajnmmi0148506

Original Article

The diagnostic value of the computed tomography scan and ultrasonography in acute appendicitis

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Received December 14, 2022; Accepted January 20, 2023; Epub February 15, 2023; Published February 28, 2023

Abstract: The most prevalent cause of emergency abdominal surgery is acute appendicitis. Ultrasonography is safe and widely available, although it's operator-dependent and difficult for people with massive bodies. Computed tomography (CT) scans are more accurate than ultrasonography, with a 93 to 98% accuracy rate. The goal of this investigation is to evaluate the diagnostic value of ultrasonography and CT scanning for acute appendicitis. This is a cross-sectional study that was performed on 231 patients with suspected with acute appendicitis. The Alvarado score was initially used to diagnose acute appendicitis. A radiologist performed abdominal ultrasonography on all patients. If the results of the ultrasonography were negative or unclear, a CT scan was performed using oral contrast. Finally, all ultrasonography and CT scan data were reevaluated by an experienced radiologist and compared to the patient's final diagnosis in the case of surgery and pathology results. Comparisons between the two groups were performed. The sensitivity, specificity, and positive and negative predictive value of ultrasonography according to pathology results in patients with low clinical suspicion were 74.9%, 63.4%, 94.3%, and 67.6%, respectively. The sensitivity, specificity, positive and negative predictive value of CT scans based on pathology results were 87.9%, 81.8%, 94.7%, and 79.3%, respectively, in patients with low clinical suspicion. The CT scan results in female patients suspected of appendicitis were completely consistent with the pathology results. The CT scan demonstrated greater specificity and sensitivity in diagnosing acute appendicitis compared to abdominal ultrasonography.

Keywords: Acute appendicitis, ultrasonography, computed tomography

Introduction

Acute appendicitis has a lifetime incidence frequency of approximately 7%. The annual incidence ranges from 96.5 to 100 incidences per 100,000 adult population worldwide, with adolescents and children facing the highest risk [1]. The most prevalent cause of emergency abdominal surgery is acute appendicitis, which must be differentiated from other sources of abdominal pain [2]. Perforation and inflammatory mass may complicate the diagnosis in 2-10% of cases when it is delayed [3]. Acute appendicitis is diagnosed using a history and physical examination, laboratory testing, and imaging [4]. With these diagnostic techniques, it is anticipated that more than 90% of patients can be diagnosed with acute appendicitis quickly and accurately, including premenopausal women for whom gynecologic diseases can mimic appendicitis and elderly patients for whom appendicitis can present with unusual clinical symptoms such as lack of leukocytosis, generalized instead of localized abdominal pain [5].

It has been observed that the negative appendectomy rate, morbidity from perforation, and hospital costs can all be reduced by as much as 15% with the use of imaging investigations in patients with a clinical suspicion of acute appendicitis [6]. When the diagnosis is unclear, CT scans and other imaging modalities have been used. In other words, imaging could be a beneficial tool because about 45% of patients do not exhibit the typical symptoms of acute

Table 1. The Alvarado score for acute appendicitis [12]

	Score
Symptoms	
Migratory of pain	1
Anorexia	1
Nausea and vomiting	1
Signs	
Tenderness in RLQ*	2
Rebound tenderness	1
Elevation of temperature > 37.3°C	1
Laboratory	
Leukocytosis	2
Shift to the left	1
Total	10

*RLQ: Right Lower Quadrant.

appendicitis [7]. In other words, about one-third of patients have normal white blood cells (WBCs) counts, and some are afebrile up to perforation. CT scans and other imaging modalities can help with the diagnosis in such a case. Ultrasonography is safe and generally available, with an accuracy rate of between 71 and 97%, but it is also very operator-dependent and challenging for individuals with massive body habits [8]. Although the use of ultrasonography is controversial, the CT scan technique is the most accurate, with an accuracy rate of between 93 and 98%. Cost, radiation exposure, and potential contrast material issues are some of the drawbacks of CT scanning [9]. In the past, there have been three main methods [8]: 1) abdominal and pelvic CT without contrast; 2) adding oral and/or intravenous contrast media; and 3) focused appendiceal CT with rectally administered contrast media (imaging only the right lower quadrant). Recent research suggests that an abdominopelvic CT scan should be the first imaging test for people with acute appendicitis [10].

An abdominopelvic CT scan has a specificity and sensitivity of 95% and 94%, respectively. CT scanning is more accurate than ultrasonography when it comes to detecting a normal appendix [7, 9]. A CT scan reveals an inflammatory appendix with a diameter greater than 6 mm, appendiceal wall thickening, and appendiceal wall enhancement after contrast media infusion. The presence of contrast or air in the appendix lumen basically rules out appendicitis. The CT scan is also a good imaging technique for distinguishing appendicitis from the majority of acute gynecological diseases, thus posing a challenge to the use of ultrasonography in women [11]. The goal of this investigation is to evaluate the diagnostic value of ultrasonography and CT scanning for acute appendicitis.

Methods and material

Study design

This is a cross-sectional study that was performed to evaluate the diagnostic value of the CT scan and ultrasonography in patients with acute appendicitis referred to Imam Khomeini Hospital in Tehran in 2020-2022. The current study was approved ethically by Tehran University of Medical Sciences.

Inclusion and exclusion criteria

Inclusion criteria include patients with the acute abdominal pain between the ages of 15 to 65 years that referred to the emergency department (ED) of Imam Khomeini Hospital in Tehran in 2020-2022. Also, written informed consent was obtained from the patients. Exclusion criteria were determined, including patients with age below 15 years and more than 65 years, symptoms less than 72 hours, immunocompromised patients, and patients with other diseases.

Study population

Two hundred and thirty-one patients that met the inclusion criteria entered the study using census method. Demographic data of patients including age, gender were obtained. All patients received a medical history, a thorough physical examination, and standard laboratory tests. Based on these observations, an initial diagnosis was formed and recorded.

Clinical findings

The Alvarado score was initially used to diagnose acute appendicitis (**Table 1**). In the majority of investigations, a score of 1-4 rules out acute appendicitis, while a score of 7 or higher confirms the diagnosis. With a score of 5-6, the patient can be watched and may require further testing. In the current study we entered the patients with Alvarado score ≥ 7 [12].

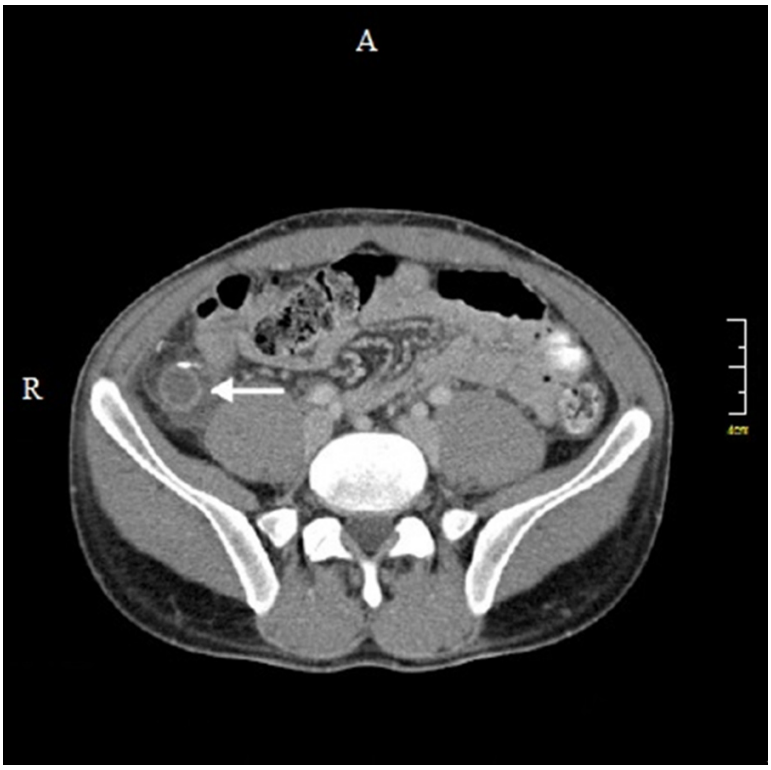

Figure 1. Abdominal CT scan in patients with acute appendicitis (white pointer).

Imaging protocol

A radiologist performed abdominal ultrasonography on all patients. Following ultrasonography, if a tentative diagnosis was made, treatment was initiated. The diagnostic criteria for appendicitis on ultrasonography were a dilated distal appendix measuring more than 6 mm in diameter with additional positive findings, including abscess, echogenic peri-appendicular fat, appendicolith, hyperemic appendiceal walls, or pericecal fluid, which was diagnostic of appendicitis. The ultrasonography report was read as negative, positive, or not visualized for acute appendicitis.

If the results of the ultrasonography were negative or unclear, a CT scan was performed using oral contrast. The radiologist reported the results of the CT scan. The diagnostic criteria for appendicitis on a CT scan were an appendix with a diameter greater than 6 mm and additional positive findings on a CT scan, such as cecal wall thickening, abscess, peri-appendicular fat stranding, appendicolith, or phlegmon, were considered diagnostic for appendicitis. The radiologist studied the CT data and determined whether it was positive or negative for appendicitis.

Finally, all ultrasonography and CT scan data were reevaluated by an experienced radiologist and compared to the patient's final diagnosis in the case of surgery and pathology results.

Statistical analysis

After collecting the study data, they were entered into SPSS software (version 25, IBM Corporation, Armonk, NY) and analyzed. The results are expressed as mean ± standard deviation. Comparisons between the two groups were performed using Student's t-test, Chi-square test or Fisher's exact test, when appropriate. *P*-value < 0.05 was considered as the significance threshold.

Result

Study population

During the study period, 360 patients with abdominal pain with clinical symptoms suspected of appendicitis were referred for examination. Among the 243 patients (67.5%) who underwent surgery, 5 had pathological data that could not be obtained despite the follow-up; therefore, they were excluded from the study. Also, seven patients with an Alvarado score lower than seven were excluded. The outcomes of 231 patients are shown below. The average age of these patients was 26.6±9 years, with a range of 15 to 65 years. One hundred five patients (45.5%) were female and 126 (54.5%) were male.

Imaging outcomes

In 69 patients (29.8%), ultrasonography was negative in terms of appendicitis, and in 9 patients (8.3%) it was suspicious, and for these 78 patients, abdominal CT scan was performed without injection of intravenous contrast material (**Figure 1**). The findings studied in these individuals' CT scans included an increase in density and inflammatory alterations around

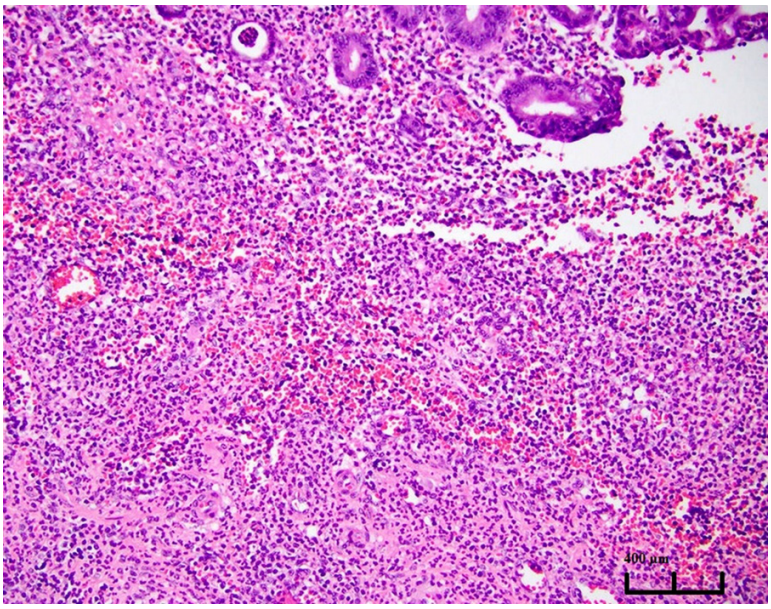

Figure 2. Pathological finding of acute appendicitis showing marked neutrophil infiltration of appendiceal wall.

Table 2. The relationship between ultrasonography and CT scan results and negative and positive appendectomy

Variables		Appendectomy		*P*-value*
		Positive	Negative	
Ultrasonography	Positive	153 (94.1%)	9 (5.6%)	0.086
	Negative	54 (78.3%)	15 (21.7%)	
CT scan	Positive	48 (94.4%)	3 (5.9%)	< 0.001
	Negative	6 (33.3%)	12 (66.7%)	

*Using Chi-square test.

Figure 3. Ultrasound imaging of acute appendicitis (white arrow shows inflamed appendix).

the appendix and the cecum; the presence of fluid or gas in the peri-appendicular region; thickening of the cecum wall and the arches of the small intestine; expansion of the cecum and the intestinal arches in the RLQ area; and the formation of an abscess or phlegmon with the appearance of appendicitis. As a pathological finding (**Figure 2**), an enlarged small intestine with a transverse diameter greater than 2.5 cm and an increase in the thickness of the cecum greater than 5 mm were assessed. When a CT scan showed no evidence of acute appendicitis and no pathological changes in other abdominal or pelvic organs, it was considered normal. In 48 patients, the CT scan findings were favorable for acute appendicitis, and the diagnosis was confirmed by the post-appendectomy pathological testing.

Comparison the imaging modalities based on appendectomy findings

In **Table 2**, the association between the ultrasonography (**Figure 3**) and CT scan results and a negative or positive appendectomy is shown. Among the individuals undergoing CT scans, three false positive and six false negative results were recorded. The CT scan revealed that the patients had reduced peritoneal fat as well as a retrocecal appendix. It appears that the anatomical position of the cecum and appendix and the lack of adequate fat around the cecum and appendix contributed to the absence of acute appendicitis symptoms and the occurrence of false-negative results. These patients may benefit from a more thorough assessment with the use of a CT scan with contrast material injection. The average age of patients with positive appendectomy was 26.6±9.2 years, and the average age of patients with negative appendectomy was 26.6±

Table 3. Sensitivity, specificity, positive and negative predictive values of CT scan and ultrasonography for diagnosis of appendicitis based on the pathological findings

Variables	Ultrasonography	CT scan
Specificity	63.4%	81.8%
Sensitivity	74.9%	87.9%
Positive predictive value	94.1%	94.4%
Negative predictive value	67.6%	79.3%

7.7 years, and this difference was not statistically significant (P = 0.417). There was no significant difference between male and female cases of negative appendectomy (P = 0.280). In 207 cases (85.2%), appendicitis was verified by pathology. In 24 cases (9.9%), pathology challenged the diagnosis of appendicitis.

Comparison the imaging modalities based on pathological findings

Table 3 shows the sensitivity, specificity, positive and negative predictive values of ultrasonography and CT scans according to the obtained pathology results. The sensitivity, specificity, and positive and negative predictive value of ultrasonography according to pathology results in patients with low clinical suspicion were 74.9%, 63.4%, 94.3%, and 67.6%, respectively. The sensitivity, specificity, positive and negative predictive value of CT scans based on pathology results were 87.9%, 81.8%, 94.7%, and 79.3%, respectively, in patients with low clinical suspicion. We evaluated the CT scan and ultrasonography based on the gender of patients. The sensitivity, specificity, positive and negative predictive values of according to pathology results in male patients were 77.7%, 61.5%, 96.5%, and 83.3%, respectively. The sensitivity, specificity, positive and negative predictive values of the CT scan according to the pathological results in male patients were 100%, 81%, 89.8% and 100%, respectively. Sensitivity, specificity, positive and negative predictive values of according to pathology results in female patients were 100%, 84.3%, 93%, and 100%, respectively. The CT scan results in female patients suspected of appendicitis were completely consistent with the pathology results.

Discussion

The most frequent cause of emergency abdominal surgery globally is appendicitis, which is characterized as inflammation of the vermiform appendix. It is still difficult for emergency physicians and surgeons to make a clinical diagnosis of acute appendicitis [3]. As a result, imaging modalities have taken on a far more significant role in the diagnostic work-up of patients who may have acute appendicitis [13]. Both CT and ultrasonography have been shown to be useful in diagnosing cases of suspected acute appendicitis [14]. The decision between ultrasonography and CT is determined by available competence and institutional preference [9, 13]. Ultrasonography is also frequently used for appendicitis diagnosis due to its widespread availability, portability, cost-effectiveness, and lack of ionizing radiation [15]. Ultrasonography is the first modality recommended by the European Association for Endoscopic Surgery (EAES) for patients with suspected appendicitis [16]. However, it is accepted that a negative ultrasonography or no visualization of the appendix does not rule out acute appendicitis [17]. Since the EAES recognizes the lower accuracy of ultrasonography in obese individuals, CT scanning is recommended as the second-line diagnostic imaging modality when ultrasonography findings are ambiguous. Due to its precision and lack of ionizing radiation exposure, ultrasonography is particularly well-suited for pediatric patients and pregnant women [18].

Our study looked at changes in the fat tissue around the appendix and cecum, the presence of fluid or gas around the appendix, appendicitis, phlegmon or peri-appendiceal abscess, increased thickness of the cecum wall and small intestine arches, dilation of the intestinal arches, and specific findings of acute appendicitis.

In the present study, 9.8% (8 cases) of patients underwent negative appendectomy according to the pathology results, but the average age and gender of patients had no significant effect on negative appendectomy cases. Also, the specificity and sensitivity of ultrasonography were 62.5% and 73.9%, respectively. However, the specificity and sensitivity of CT scan were 80.9 and 88.8%, respectively. In the current study, only the surgical cases that had pathological results were investigated, and the other cases that were ruled out by CT scan and clinical examinations and probably had negative pathology were not included in the study, so it seems that it is possible to CT scan was

used well in the diagnosis of acute appendicitis.

In 2022, Naidu and others [19] conducted a study on 200 patients to compare ultrasonography abdomen and CT scan for the diagnosis of acute appendicitis. In comparison to abdominal ultrasonography, they discovered that CT scan diagnosis of acute appendicitis had greater sensitivity, positive predictive value, and a negative appendectomy. Despite this, they highly recommend that CT scans be used to review all negative ultrasonography results to rule out acute appendicitis, even though they are far faster to conduct and spare most patients from ionizing radiation and contrast. A "first-pass" strategy using ultrasonography first and subsequently CT, if the ultrasonography is not diagnostic, may be preferable to balance test performance with adverse effects and ED patient throughput times. In another study [20], 69 and 18 patients were evaluated by ultrasonography and CT scan, respectively. In this study, it was discovered that CT scanning can alter the treatment plan in uncertain situations, minimize hospital stay duration and expenses, decrease the complication rate and negative laparotomy rate, and decrease conversion to open surgery. Also, the researchers thought that a CT scan (rather than ultrasonography) was a better way to detect and manage acute appendicitis and its consequences. Our study is in line with this study. However, the significant point of our study was the statistical population, which can make the results more reliable.

In 2018, Leung and colleagues [10] evaluated the clinical findings of appendicitis following radiological imaging. Of the 37 patients with appendicitis found on ultrasonography, 11 received a CT scan to confirm their ultrasonography results; all were negative, and so these patients were discharged from the hospital without treatment. Among 55 patients, 46 were found to have appendicitis on imaging but did not have it (positive predictive value = 16.4%). Appendectomy was performed on 21 individuals, and only 9 of them had histological evidence of appendicitis. This study found that ultrasonography and CT scans may not properly predict acute appendicitis. Clinical discretion should determine initial treatment, follow-up testing, and imaging. This study in contrast with our study and also the above mentioned studies. This inconsistency may be the result of the statistical population limitations of this study.

Since this study was conducted cross-sectional, it was not possible to match the age and gender of the patients who underwent ultrasonography and a CT scan. This is the most important limitation of the present study. On the other hand, in the CT scans performed on the female, intravenous contrast was not used. To make the results more general, it would be best to do a study with a CT scan with intravenous contrast on this group of patients.

Conclusion

The CT scan demonstrated greater specificity and sensitivity in diagnosing acute appendicitis compared to abdominal ultrasonography. Despite this, we highly recommend that every negative ultrasonography be followed up with a CT scan to rule out acute appendicitis, despite the fact that it was significantly faster and avoided contrast and ionizing radiation in the majority of patients.

Disclosure of conflict of interest

None.

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