

Diagnostic value of appendicular Doppler ultrasonography in acute appendicitis

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ABSTRACT

BACKGROUND: Acute appendicitis is one of the most common causes of acute abdominal pain prompting emergency department (ED) visits. It is critical for the physicians to promptly and accurately diagnose acute appendicitis. The present study aimed to evaluate the diagnostic efficacy of Doppler ultrasonography (USG) in patients with acute appendicitis and compare this new method with other commonly used radio-diagnostic tools.

METHODS: All patients who were diagnosed with acute appendicitis at the Kecioren Training and Research Hospital ED and later underwent appendectomy between October 2012 and April 2013 were included in the study. Approval from the ethics committee was obtained for this prospective study. The patients' demographic information, physical examination findings, vital signs, Alvarado scores, and laboratory and radiological exam results were recorded.

RESULTS: A total of 60 patients were enrolled in the study. In 46 of the 60 patients, diagnosis of acute appendicitis was confirmed by histopathology results, whereas 14 patients, diagnoses was not confirmed by lab tests. Doppler USG could detect 43 of the 46 patients as true positives, and it detected 2 of the 14 patients with negative lab results as false positives. For diagnosis of acute appendicitis, sensitivity of appendicular Doppler USG was 93%, specificity was 85%, accuracy was 91%, positive likelihood ratio was 6.5, and negative likelihood ratio was 0.08.

CONCLUSION: Doppler imaging can offer a high level of diagnostic success in patients with acute appendicitis. Appendicular Doppler USG offers a rapid and easy application without the need to expose patients to contrast medium and is superior to both USG and computed tomography. Therefore, we recommend the use of appendicular Doppler imaging as the primary radiological exam in diagnosing acute appendicitis.

Keywords: Acute appendicitis; appendicular Doppler ultrasonography; emergency radiology.

INTRODUCTION

Acute appendicitis is one of the most common abdominal pathologies requiring surgical intervention.^[1] A prompt diagnosis is necessary to avoid complications, such as gangrene and perforation. In addition, delayed surgical intervention increas-

es the chances of complications and delayed diagnosis may result in life-threatening conditions, such as abscess, peritonitis, or sepsis.^[2,3] The time interval between diagnosis and surgical intervention is a determinant in the risk of perforation.^[4] The diagnosis of acute appendicitis is initially made with a physical examination; in addition, laboratory and radiological exams are used to support a suspected diagnosis. Currently, plain radiographs, ultrasonography (USG), and computed tomography (CT) are among the commonly used radio-diagnostic methods. However, none can diagnose the condition alone;^[1] thus, new diagnostic methods are needed in this field. The present study aimed to evaluate the diagnostic effectiveness of Doppler USG in patients with acute appendicitis and to compare this new method with other commonly used radio-diagnostic tools.

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MATERIALS AND METHODS

Ethical committee approval was obtained before this prospective study, which included patients aged 18–65 years who presented to the Emergency Department (ED) of the Kecioren Training and Research Hospital with complaints related to abdominal pain; they were diagnosed with acute appendicitis and underwent appendectomy between October 2012 and April 2013. Owing to the absence of any radiologist who can perform Doppler USGs between 5 pm to 8 am, the study included only those patients who were admitted between 8 am to 5 pm. Therefore, exclusion criteria included being admitted after 5 pm, being under 18 or over 65 years of age, having had an appendectomy, pregnancy, lack of consent, and having presented to the ED more than 24 hours after the onset of abdominal pain.

Clinical findings, physical, and radiological exams and laboratory results were recorded for all patients. History, physical exam results, and laboratory findings were used to calculate each patient's Alvarado score. Patients who scored ≥ 8 on a scale of 10 were considered as probable cases of acute appendicitis; those who scored 5–7 were considered possible cases; and those who scored 4 or below were considered unlikely to have acute appendicitis. USG, Doppler USG, and contrast-enhanced CT were performed on all study patients. USG and Doppler USG were conducted by separate radiologists, each of whom was blinded to the results of the other examiner. A third radiologist read the CT scans. Following these examinations, the patients were referred to general surgeons. After their appendectomies, the histopathology (HPE) results of all patients were recorded. This study recognized pathological confirmation as the gold standard diagnostic method.

Based on the results of appendicular Doppler USG, patients were grouped as either edematous or perforated. Blood flow to the appendix and temperature were measured and compared with the pathology results. All Doppler examinations were performed by B-mod using a Toshiba SSA-770A ultrasound machine equipped with a 5 MHz color and pulse Doppler and a 3–9 MHz electronic phased array probe. Appendices were first located by a radiologist. Systolic and diastolic blood flows were measured, and the resistance index (RI) and pulsatility index (PI) values were calculated using peak systolic blood flow velocity and end diastolic flow velocity.

Statistical Analysis

Statistical analysis of the data was performed using the Statistical Package for Social Sciences (SPSS) 13.0 software. Chi-square and analysis of variance (ANOVA) tests were used to compare differences between the groups. A p-value of <0.05 was considered statistically significant.

RESULTS

The study originally included 92 patients who had been diag-

nosed with acute appendicitis. The study excluded 32 patients for reasons like missing data, lack of consent, and technical problems (the linear probe malfunctioned one day). Of the 60 patients who met the inclusion criteria for the study, the mean age was 30.3 years (min-max: 19–61 years), and 33 patients (55%) were male. Table 1 shows patients' demographic variables, vital signs, laboratory findings, Alvarado scores, and histopathology (HPE) results.

In 46 patients, the clinical diagnosis of acute appendicitis was concordant with the pathology, while in 14 patients, the clinical diagnosis could not be confirmed by pathology results. Of these 46 patients, the USG detected 43 as true positives, and of the 14 patients whose diagnosis was not confirmed by HPE, it detected 6 as false positives. Of the 46 patients, the CT detected 39 as true positives, and of the 14 patients who had negative pathology, it detected 5 as false positives.

Table 1. Patient's demographic variables, vital signs, laboratory findings, Alvarado scores, and pathological results

	n	%
Sex		
Female	33	55
Male	27	45
Temperature		
Normal ($<37^{\circ}\text{C}$)	31	52
Sub-febrile (37°C – 38.3°C)	21	35
High fever ($>38.3^{\circ}\text{C}$)	8	13
Heart rate		
Normal	49	82
Tachycardia	11	18
Systolic blood pressure (SBP)		
Normal (90 mmHg $<$ SBP $<$ 150 mmHg)	52	87
Hypotension ($<90\text{ mmHg}$)	8	13
Body mass index		
<20	32	53
20–25	20	33
>25	8	13
Pathology confirmation		
Confirmation	46	77
No confirmation	14	23
White blood cell		
$>11.000/\text{mm}^3$	39	65
$<11.000/\text{mm}^3$	21	35
Alvarado scores		
1–4 points	22	37
5–7 points	23	38
8–10 points	15	25

Table 2. Comparison of computed tomography, ultrasonography, and appendicular Doppler ultrasonography findings % (95%CI)

	Ultrasonography	Abdominal computed tomography	Doppler ultrasonography
Sensitivity	93 (82–98)	84 (71–93)	93 (82–98)
Specificity	57 (28–82)	64 (35–87)	85 (57–98)
Accuracy	85 (69–92)	80 (65–90)	91 (82–98)
Positive likelihood ratio	2.1 (1.1–4.0)	2.3 (1.1–4.8)	6.5 (1.8–23.6)
Negative likelihood ratio	0.1 (0.03–0.3)	0.2 (0.1–0.5)	0.08 (0.02–0.2)
Positive predictive value	87 (75–95)	88 (75–96)	95 (84–99)
Negative predictive value	72 (39–93)	56 (29–88)	80 (51–95)

Finally, of the 46 patients, the Doppler USG detected 43 as true positives, and of the 14 patients with negative pathology, it detected 2 as false positives. Table 2 shows sensitivity, specificity, accuracy, positive likelihood ratio (PLR), negative likelihood ratio (NLR), positive predictive values (PPV), and negative predictive values (NPV) of the Doppler USGs, USGs, and CTs.

Of the 46 patients, 25 with acute appendicitis were at the edematous histopathological stage and 21 were at the perforated stage. In particular, of the 43 patients whose diagnosis was confirmed by Doppler USG, 21 were at the edematous stage and 20 were at the perforated stage. Although two patients were diagnosed to be at the perforated stage by Doppler USG, the results were not confirmed by HPE. The mean RI and PI index were calculated as 0.78 and 1.2, respectively, at the edematous stage, while the mean RI and PI index were 0.81 and 1.0, respectively, at the perforated stage. The sensitivity of the Doppler USG in detecting pathology during the edematous stage was 90%, the PPV was 100%, and the accuracy was 95%.

DISCUSSION

We determined the sensitivity of appendicular Doppler USG to be 93%, its specificity to be 85%, its accuracy to be 91%, its PLR to be 6.5, and its NLR to be 0.08. Based on these findings, the Doppler method was more accurate than conventional methods, such as USG and CT. The diagnostic accuracy of the Doppler USG was 86% in cases of perforated appendicitis and 95% in cases of edematous appendicitis.

Diagnosing acute appendicitis is not always easy, and the time spent in arriving at diagnosis leads to delayed surgical intervention, which in turn causes related complications.^[2] Akyıldız et al. investigated whether acute appendicitis and perforated appendicitis are different clinical entities.^[5] They found that the two were not different clinical entities and that perforated appendicitis was a pathology developed after progressive acute appendicitis. They also found that the time required to prepare for surgical intervention was longer in cases of perforated appendicitis.

The use of diagnostic imaging modalities in patients with suspected acute appendicitis reduces the time it takes to decide on the method of surgical intervention, decreases the possibility of negative appendectomy, and reduces both the cost and morbidity related to delay in diagnosis and treatment.^[6] USG is commonly used to image acute appendicitis and is inexpensive, rapid, and noninvasive and has sensitivity of 78%–96% and specificity of 85%–98%.^[7] In a study conducted by Hussain et al., the sensitivity of USG in patients with an appendix root diameter ≥ 7 mm was 88%, specificity was 92%, PPV was 94%, NPV was 84%, and accuracy was 90%. The study measured the diagnostic success of USG imaging by evaluating the diameter of the appendix. In the present study, the sensitivity of USG was 93%, specificity was 57%, PPV was 87%, NPV was 72%, and accuracy was 85%. This shows that the PPV or sensitivity values of USG in the present study were comparable to those in the literature; however, the specificity value was low compared to those obtained by other studies. One reason for these findings could be that USG is a user-dependent method, which can explain the variations in the results. In addition, the present study did not measure the root diameter of the appendices, and this could be the reason for low accuracy of USG in diagnosing newly developed acute appendicitis.^[8]

The related literature shows that the sensitivity of CTs ranges from 87%–100% and specificity from 83%–100%.^[3] The CT can be considered as having more valuable diagnostic properties than the USG. In the present study, the sensitivity of CT exams was 84%, specificity was 64%, PPV was 88%, NPV was 56% and accuracy was 80%. Except for the sensitivity, all the CT values obtained in the present study were relatively low compared to those in the literature. This could be due to the small number of patients enrolled in the study and the fact that all CT images were evaluated by the same radiologist.

In their study Aranda et al., found that CTs had higher sensitivity than USGs, but both had similar PPVs. The authors concluded that both USGs and CTs were useful diagnostic tools in acute appendicitis; however, they recommended other radio-diagnostic tools that provide higher specificity and sensitivity in diagnosing acute appendicitis.^[9]

Doppler evaluation is effective in detecting increased blood flow, hyperemia, and temperature increases during inflammation. The use of Doppler significantly increases the sensitivity and accuracy of USG. Doppler imaging is particularly effective in detecting hyperemia, inflammation, and edema, all of which are present during the first stage of acute appendicitis. On the other hand, the diagnostic accuracy of Doppler is reduced by conditions that impair blood flow, such as necrotic and gangrenous appendicitis. In the present study, no patients had necrotic or gangrenous appendicitis, and the study grouped patients based on the stages of their appendicitis: edematous (inflamed), 21 patients; and perforated, 22 patients. Of those in the edematous stage, the Doppler results had near-complete agreement (95%) with the pathology results, except in the cases of two patients who had perforated appendicitis. While of those patients in the perforated stage, the Doppler USG results agreed with the pathology results in 86% of cases. These results are consistent with those in the literature, which report high rates of diagnostic success with contrast-induced appendicular Doppler imaging used to diagnose acute appendicitis.^[10]

Some studies have compared abdominal CT and Doppler USG. One such study, by Gaitini et al., compared the diagnostic values of appendicular Doppler USG and CT in patients with acute appendicitis and found that Doppler's sensitivity was 74.2%, specificity was 97%, PPV and NPV were both 88%, and accuracy was 93%. In contrast, they found that CT offered superior results, with a sensitivity of 100%, specificity of 98.9%, PPV of 97.4%, NPV of 100%, and accuracy of 99%. The authors suggested examining patients suspected of having acute appendicitis with a USG first to reduce costs and prevent unnecessary exposure to radiation. They recommended using CT examination only to confirm diagnoses in cases in which USG was not sufficient.^[11]

Gutierrez et al. investigated the correlation between USG and Doppler in diagnosing acute appendicitis and found a sensitivity of 90% and a specificity of 94%. They attempted to improve the diagnostic accuracy of USG for acute appendicitis by adding Doppler imaging. The authors suggested using both USG and Doppler imaging to diagnose acute appendicitis.^[12]

In a similar study, Incesu et al. compared USG, Doppler USG, and contrast-induced appendicular Doppler USG in diagnosing acute appendicitis. They evaluated hyperemia and RI (resistance index) for the appendix by using both appendicular Doppler USG and contrast-induced appendicular Doppler USG and compared the outcomes with the pathology results. Their study revealed that appendicular Doppler USG had 80% accuracy and 74% sensitivity in suppurative and gangrenous appendicitis, while contrast-induced appendicular Doppler USG had 98% accuracy and 100% sensitivity. The

authors concluded that contrast-induced Doppler USG had near-complete accuracy in both inflamed and gangrenous appendicitis and that it is a strong candidate for being the most valuable diagnostic tool to diagnose acute appendicitis.^[10]

Conclusions

In conclusion, Doppler imaging provides a high level of diagnostic success in patients with acute appendicitis. Appendicular Doppler USG features rapid, easy application, without the need to expose patients to a contrast medium, and it is more accurate than either USG or CT. Therefore, we recommend the use of appendicular Doppler imaging as the primary radiological examination method to diagnose acute appendicitis.

Conflict of interest: None declared.

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ORIJİNAL ÇALIŞMA - ÖZET

Akut apandisitte appendiküler Dopplerin tanısal değeri

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AMAÇ: Akut apandisit ani başlangıçlı karın ağrısı nedeni ile acil servis başvurularında en sık karşılaşılan nedenlerden birisidir. Hekimler için akut apandisit tanısının zamanında ve doğru olarak konulması kritiktir. Bu çalışmanın amacı akut apandisit tanılı hastalarda Doppler ultrasonografinin (USG) tanısal değerliliğini değerlendirmek ve bu yeni tanısal metodu diğer sık kullanılan tanısal metotlarla karşılaştırmaktır.

GEREÇ VE YÖNTEM: Ekim 2012 ile Nisan 2013 arasında Keçiören Eğitim ve Araştırma Hastanesi'ne başvuran ve akut apandisit tanısı alan sonrasında ise apendektomiye alınan hastalar çalışmaya dahil edildi. İleriye yönelik olan çalışmaya başlanmadan önce lokal etik kuruldan izin alındı. Hastaların demografik verileri, fizik muayene bulguları, vital bulguları, Alvarado skorları, radyoloji ve laboratuvar sonuçları kayıt edildi.

BULGULAR: Toplamda 60 hasta çalışmaya dahil edildi. Kırk altı hasta yapılan cerrahi sonrası patolojik olarak apandisit tanısı doğrulanırken 14 hasta patolojik sonuçlarla doğrulanmadı. Doppler USG 46 hastanın 43'ünü doğru pozitif olarak saptayabilirken iki hastayı yanlış pozitif olarak yorumladı. Doppler USG duyarlılığı 0.93, özgüllüğü 0.85, doğruluk 0.91, pozitif likelihood ratio (PLR) 6.5 ve negatif likelihood ratio 0.08 olarak bulundu.

TARTIŞMA: Doppler USG akut apandisit hastalarının tanı sürecinde yüksek seviyede başarılı gibi görünmektedir. Hızlı ve kolay uygulanabilmesi, hastaya kontrast madde verilmemesi nedenleri ile klasik USG ve bilgisayarlı tomografiye üstün gibi görünmektedir. Biz bundan dolayı Doppler USG'nin akut apandisit tanısında öncelikle kullanılması gerektiğini önermekteyiz.

Anahtar sözcükler: Acil radyoloji; akut apandisit; appendiküler doppler USG.

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