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The ability of emergency medicine physicians to diagnose acute appendicitis: A cross-sectional, prospective study

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Abstract

Acute appendicitis (AA) is a common diagnosis that requires surgical treatment. Bedside ultrasound (BUS) is a very useful tool in emergency medicine (EM). We aimed to evaluate the skills of emergency medicine specialists performing bedside ultrasound (EMUS) in patients with suspected AA. In this prospective, cross-sectional study, 200 patients presenting to the emergency department (ED) with acute abdominal pain between January 1 and December 31, 2015, were evaluated. First, an EM specialist performed BUS, followed by a formal ultrasound (US) and surgical consultation when indicated. Initial diagnoses, hospital admission or ED discharge, and final diagnoses were documented via biopsy or telephone follow-up. Comparisons were made using ROC curve analysis. A total of 192 patients were included in the study (mean age: 32.4±12.8 years; 52.1% female, 47.9% male). AA was reported in 47.0% of patients who underwent computed tomography (CT) (p=0.001). The values measured for US (RUS) and EMUS performed by radiology in the diagnosis of AA were: sensitivity (63.64% and 77.53%) and specificity (92.31% and 72.38%), respectively. AUC values were 0.78 and 0.75. RUS was found to be statistically significantly better in diagnosing AA (p=0.032). Although EMUS had higher sensitivity in ruling out AA, there was no statistically significant difference compared to RUS (p=0.156). EMUS is a useful tool in the diagnosis of AA. It can be used by emergency medicine specialists to diagnose AA earlier, prevent delays in surgery, and reduce radiation exposure by eliminating the need for CT imaging.

Keywords: Acute appendicitis, bedside ultrasound, emergency radiology

Introduction

Acute appendicitis (AA) is an inflammatory condition of the vermiform appendix and is one of the most common surgical emergencies worldwide. The risk of developing appendicitis in the general population is approximately 7–10%. Although the disease can affect individuals of all age groups, the highest incidence occurs between the ages of 20 and 30 [1]. If not diagnosed and treated in a timely manner, this condition carries significant risks of morbidity and mortality [2].

The clinical symptoms of acute appendicitis classically include periumbilical pain that radiates to the right lower quadrant. This pain is typically accompanied by nausea, vomiting, and a low-grade fever.

The diagnosis is usually made based on a combination of the patient's history, physical examination, biochemical analyses, and diagnostic imaging results [3]. The prognosis of patients is directly related to the speed of diagnosis and the effectiveness of treatment [4].

Performing an ultrasound in the radiology department may lead to delays in diagnosis because the procedure can be time-consuming. However, ultrasound is a fast and safe imaging technique that avoids exposure to radiation. Computed tomography (CT) imaging is considered the definitive diagnostic method for acute appendicitis. Nevertheless, this method increases the risk of cancer development due to ionizing radiation, which is a significant concern for pediatric and pregnant patients [2]. Performing ultrasonography (US) in the radiology department can be time-consuming and may lead to diagnostic delays. However, ultrasonography is a rapid and safe imaging technique that avoids exposure to radiation [5].

When performed by emergency medicine (EM) specialists,

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bedside ultrasound (BUS) is beneficial even in busy emergency department settings. This technique helps EM physicians assess patients and make decisions more quickly, reduces the workload of the radiology department, and shortens the length of stay in the emergency department [6]. Several articles have been published on the accuracy of BUS in diagnosing appendicitis in the emergency department [7]. However, there are no comparative studies evaluating the use of ultrasound performed by emergency medicine specialists (EMUS) versus that performed by radiology specialists (RUS) in diagnosing appendicitis. The ability of emergency physicians to perform accurate bedside ultrasound for appendicitis diagnosis can significantly affect patient flow, shorten diagnosis time, and reduce healthcare costs [8].

There fore, this study aimed to determine the accuracy of emergency medicine specialists performing bedside ultrasound in patients with suspected AA.

Material and Methods

This observational prospective study was conducted following approval by the Istanbul Medipol University Non-Interventional Clinical Research Ethics Committee (Decision No: E-10840098-772.02-5414). The study took place between January 1, 2015, and December 31, 2015, at the Emergency Department of Haydarpaşa Numune Training and Research Hospital.

Study Population and Sample Size Calculation: Based on previous literature reporting that the sensitivity of ultrasound for appendicitis diagnosis ranges between 60% and 85% [9], the required sample size was calculated to be 180 patients to detect a 15% difference in diagnostic accuracy between EMUS and RUS, with 80% power and a 5% significance level. Taking possible dropout rates into account, 200 patients were included in the study.

The inclusion criteria for the study were as follows: being over 18 years of age, presenting to the emergency department with abdominal pain, having a suspicion of acute appendicitis by the attending physician in the emergency department, and providing informed consent.

The exclusion criteria for the study were as follows: being under 18 years of age, pregnancy, previous appendectomy, unstable vital signs, and lack of informed consent for the study.

After taking patient histories and performing physical examinations, both EM physicians and radiology specialists performed US examinations using the Mindray M7® model ultrasound system.

A 5–10 MHz linear transducer (Mindray® Bio-Medical Co., Shenzhen, China) was used. Dynamic B-mode images of the appendix were obtained. This procedure took approximately five and a half minutes on average. Each physician group recorded the initial diagnoses, decisions regarding admission to the emergency department or discharge, and the definitive diagnosis based on the postoperative pathological specimen. Follow-up after hospital discharge was conducted by telephone to determine 1-week and 1-month mortality rates.

Pathological findings, surgical outcomes, and outpatient follow-up data were evaluated to establish the definitive diagnosis of appendicitis or an alternative medical condition; this diagnosis, based on biopsy findings, was accepted as the reference standard. Patients who were discharged or not operated on after observation were followed up by telephone. Subsequently, the diagnostic utility and accuracy were evaluated by comparison with EMUS and RUS.

Three EM specialists with no prior experience using bedside ultrasound (BUS) for appendicitis diagnosis were randomly selected and given a one-day training course. This intensive programme covered ultrasound applications for various conditions, including trauma guidance, intrauterine pregnancy, abdominal aortic aneurysms, cardiac evaluations, biliary system assessments, urinary tract examinations, deep vein thrombosis detection, musculoskeletal imaging, thoracic scans, ocular evaluations, and medical procedures. Following this introductory programme, participating physicians attended a 6-hour training module focused on appendicitis assessment, delivered by an experienced radiologist. In this advanced session, they received practical, hands-on training with 25 patients to develop their skills in diagnosing AA. For these training programmes, we adhered to the Point-of-Care Ultrasound (IFOCUS) Curriculum Guide developed by the International Federation for Emergency Medicine [10]. A doctor from the USgroup participated in each working shift.

The diagnosis of AA in patients was made by EM specialists using BUS based on the following criteria: an anteroposterior diameter of the appendix exceeding 6 mm, a non-compressible appendix with absent peristalsis, anechoic fluid accumulation around the appendix, a 2 mm increase in the thickness of the appendix wall, presence of appendicoliths, and the appearance of the ultrasonographic McBurney sign. Patients were evaluated by one of three radiology specialists during night shifts. These specialists were not informed of the working protocol. Ultrasound examinations by radiologists were performed approximately 30 minutes after the emergency medicine specialist's BUS. When necessary, a surgeon—who was also unaware of the working protocol—was consulted. The ultrasound reports were independently prepared by emergency medicine specialists and radiology specialists, who were blinded to each other's findings. However, general surgeons were unaware of the emergency medicine specialists' ultrasound reports but had access to the radiology specialists' reports. The BUS performed by the emergency medicine specialists was a focused ultrasound limited to diagnosing AA and did not include assessment for other abdominal pathologies.

Statistical Methodology

Data analysis was performed using MedCalc statistical software, version 15.2.2 (MedCalc Software bvba, Ostend, Belgium; http://www.medcalc.org; 2015). Normality of continuous variables was assessed using the Shapiro-Wilk test. Categorical variables were compared using the chi-square test or Fisher's exact test as appropriate. For continuous variables, Student's t-test was used for normally distributed data, and the Mann-Whitney U test was used for non-normally distributed data. The Kruskal-Wallis H test was applied for multiple group comparisons.

Data were presented as mean±standard deviation or median (minimum-maximum) as appropriate. Logistic regression analysis was performed to identify independent predictors of appendicitis diagnosis. Receiver operating characteristic (ROC) curve analysis was conducted to determine threshold values of parameters for distinguishing groups and based on significant results from multivariate analysis. Kaplan-Meier survival analysis and log-rank tests were applied for follow-up data analysis.

Correlation and regression analyses were used to assess agreement between groups. Agreement analyses were performed using Cohen's weighted Kappa statistics for clinicians in each group. Clinical benefit predictors were calculated using a designated online tool (Richard Lowry, Professor Emeritus, Department of Psychology, Vassar College, accessible at vassarstats.net).

A p-value below 0.05 was considered statistically significant.

Result

Inter- observer reliability assessment was performed prior to patient enrollment. Two groups, each consisting of three physicians, evaluated 30 patients (n=16 for EMUS and n=14 for RUS). Before enrollment, 16 patients were evaluated by three emergency physicians (EP), and the findings were analyzed. For the initial diagnosis of appendicitis, the calculated intraclass correlation coefficient (ICC) indicating absolute agreement (n=14) was 0.91 (95% CI: 0.80–0.97). The absolute agreement for appendicitis diagnosis among the three radiologists in the RUS group (n=14) was 0.90 (95% CI: 0.63–0.92).

During the study period, 954 patients with a preliminary diagnosis of AA were admitted to our hospital's emergency department. Of these, 118 were under 18 years of age, 436 declined to participate in the study, 59 had unstable vital signs, 107 were pregnant, and 34 had previously undergone appendectomy; 754 patients were excluded from the study. In this study, a total of 200 patients underwent BUS due to suspected AA. BUS was performed on all of these patients (n=200) by an emergency medicine specialist, while radiologists performed US on 198 patients in the same group. Among these cases, eight patients were excluded from the statistical analysis: two patients for whom the radiology department could not perform US, and six patients with unclear histopathological diagnoses who could not be followed up. Thus, 192 patients were included in the final data analysis. We only followed up on mortality, and our records showed no unplanned readmissions in our patient sample. The patient flow chart is presented in Figure 1. The basic demographic and clinical characteristics of the study participants are detailed in Table 1.

Emergency appendectomy was performed on 88 (44%) of the evaluated patients. All patients who underwent appendectomy had a prior abdominal CT scan. Among those who underwent CT, 37 (47.0%) were diagnosed with AA; 20 (22.7%) had normal findings; 13 (14.8%) had ovarian pathology; 6 (6.8%) had kidney, adrenal gland, or urethral pathology; 4 (4.5%) had uterine pathology; 4 (4.5%) had diverticulitis; and 4 (4.5%) had inflammatory bowel disease (IBD). Of the patients who underwent surgery, 86 (97.7%) were pathologically confirmed to have appendicitis, while 2 (2.3%) were found to have ovarian pathology.

Of the 112 patients who did not undergo surgery and were clinically diagnosed and followed up, 77 (68.7%) were found to have non-specific abdominal pain, ovarian pathology was detected in 7 (6.2%), kidney pathology in 8 (7.1%), and urinary tract infection in 4 (3.6%).

Inflammatory bowel disease (IBD) was detected in 3 patients (2.7%), diverticulitis in 3 patients (2.7%), ectopic pregnancy in 1 patient (0.9%), pelvic inflammatory disease in 1 patient (0.9%), and uterine pathology in 1 patient (0.9%), Follow-up was not possible for 6 patients (5.4%). Diagnosis by method is presented in Table 2.

Diagnostic Performance Analysis. In the statistical sensitivity assessment, the criteria determined for BUS in AA diagnosis were as follows: sensitivity 63.64% (95% CI 52.69-73.63), specificity 92.31% (95% CI 85.40-96.62), accuracy (AUC) 0.78 (95% CI 0.71–0.84), positive likelihood ratio 8.27 (95% CI 4.17–16.40), negative likelihood ratio 0.39 (95% CI 0.30–0.52), positive predictive value 87.50% (95% CI 76.85–94.45) and negative predictive value 75% (95% CI 66.58–82.23).

The criteria obtained for EMUS in AA diagnosis are as follows: 77.53% sensitivity (95% CI 67.45–85.70), specificity 72.38% (95% CI 62.80–80.66), AUC 0.75 (95% CI 0.68–0.81),

2.81 positive likelihood ratio (95% CI 2.02–3.90), 0.31 negative likelihood ratio (95% CI 0.21–0.46), 70.41% positive predictive value (95% CI 60.34-79.21) and 79.17% negative predictive value (95% CI 69.67-86.79) were obtained.

According to the evaluation, RUS was found to be statistically significantly better in diagnosing AA (p=0.032). However, EMUS has higher sensitivity in ruling out AA; no statistically significant difference was found when compared to RUS (p=0.156).

In the kappa analysis performed to determine the agreement between RUS and EMUS in evaluating AA, the kappa coefficient (weighted kappa) was measured (weighted kappa) κ: 0.455±0.0595 (95% CI 0.338-0.571).

Based on these values, moderate agreement was found between RUS and EMUS.

No adverse events occurred as a result of the application of the test (BUS).

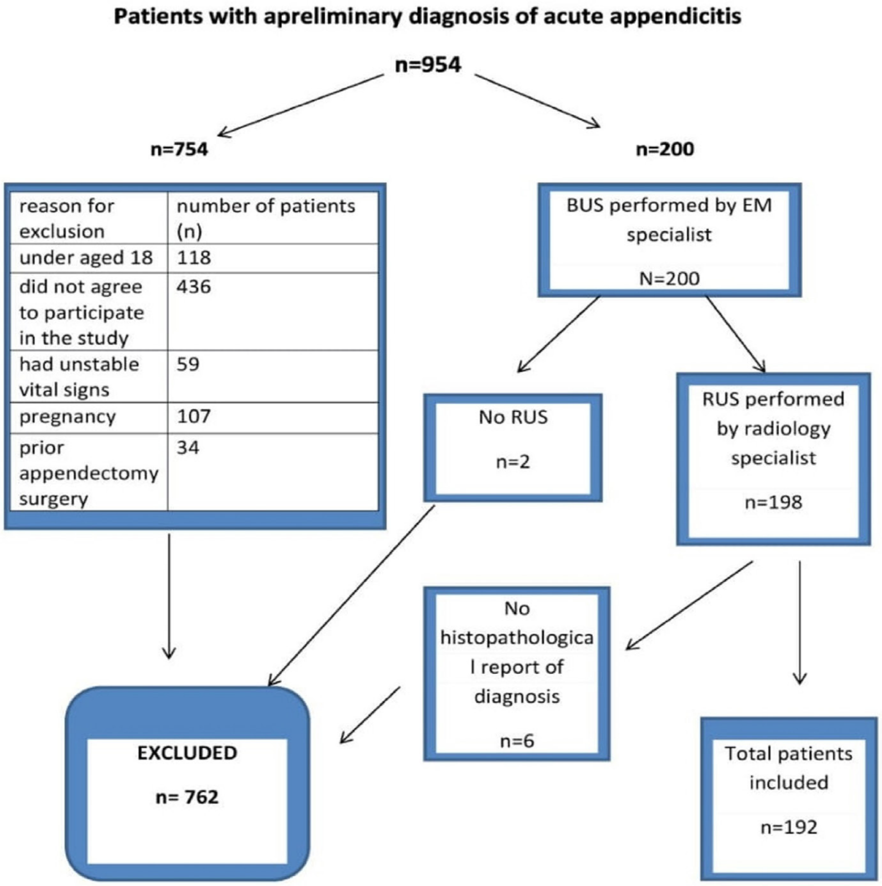

Figure 1. Flow of participants

Table 1. Baseline demographic and clinical characteristics of patients for the study population

Category	Characteristics	Number of patients (n)
Demographics	**Median age (years)**	30 (23-40.5)
	Male	87 (43.5%)
	Female	113 (56.5%)
History	**Duration of pain (hours)**	24 (8-48)
	RLQ pain	196 (98%)
	Migration of pain to RLQ	97 (48.5%)
	Anorexia	122 (61%)
	Nausea & vomiting	127 (63.5%)
	Self-administration of analgesics during episode	47 (23.5%)
Physical examination	**Temperature >37.3°C**	53 (26.5%)
	Rebound Tenderness	153 (76.5%)
Scores (point)	**Alvarado score (median, IOR)**	6 (5-8)
Laboratory results	**WBC count (/mm^3) (median, IQR)**	11.79 (8.29-14.81)
	Neutrophils (%) (median, IQR)	74.35 (65.2-83.15)
Radiology, surgery, lost to follow up	**CT performed**	88 (44%)
	Surgery performed	88 (44%)
	EMUS	200 (100%)
	Lost to follow up	6 (3%)

IQR: interquartile range between 2-75 percentiles, CT: computed tomography, RLQ: right lower quadrant, EMUS: bedside ultrasonography performed by emergency medicine specialist, RUS: ultrasonography performed by radiology specialist

Table 2. Diagnosis according to diagnostic modality

Diagnostic modality	Diagnosis	Number of patient (n)
CT results (n=88)	Acute appendicitis	37 (42%)
	Normal	20 (22.7%)
	Ovarian pathologies	13 (14.8%)
	Renal, surrenal and ureteral pathologies	6 (6.8%)
	Uterine pathologies	4 (4.5%)
	IBD	4 (4.5%)
Histopathological diagnosis (operated) (n=88)	Acute appendicitis	86 (97.7%)
	Ovarian pathologies	2 (2.3%)
Clinical diagnosis and follow up (n=112)	NSAP, no operation	77 (68.7%)
	Ovarian pathologies	7 (6.2%)
	Renal pathologies	8 (7.1%)
	Lost to follow up	6 (5.4%)
	UTI	4 (3.6%)
	IBD	3 (2.7%)
	Diverticulitis	3 (2.7%)
	Ectopic pregnancy	1 (0.9%)
	Gastroenteritis	1 (0.9%)
	PID	1 (0.9%)
	Uterine pathologies	1 (0.9%)

CT: computed tomography, NSAP: non-specific abdominal pain, UTI: urinary tract infection, IBD: inflammatory bowel disease, PID: pelvic inflammatory disease

Table 3. Results (with 95% confidence intervals) of RUS and EMUS in the diagnosis of acute appendicitis

Diagnostic parameters	RUS	EMUS
Sensitivity %	63.64 (52.69-73.63)	77.53 (67.45-85.70)
Specificity %	92.31 (85.40-96.62)	72.38 (62.80-80.66)
Accuracy	0.78 (0.71-0.84)	0.75 (0.68-0.81)
+ likelihood ratio	8.27 (4.17-16.4)	2.81 (2.02-3.9)
- likelihood ratio	0.39 (0.3-0.52)	0.31 (0.21-0.46)
PPV %	87.5 (76.85-94.45)	70.41 (60.34-79.21)
NPV %	75 (66.58-82.23)	79.17 (69.67-86.79)

RUS: Ultrasonography performed by radiology specialist, EMUS: Bedside ultrasonography performed by emergency medicine specialist, PPV: Positive predictive value, NPV: Negative predictive value

Discussion

This prospective study demonstrated that emergency medicine specialists can effectively perform bedside ultrasound examinations for the diagnosis of acute appendicitis. However, ultrasound examinations performed by radiologists were found to provide superior specificity and overall diagnostic accuracy. Our findings revealed that EMUS provided higher sensitivity (77.53%, 63.64% respectively) but lower specificity (72.38%, 92.31% respectively) compared to RUS. RUS, on the other hand, was found to have statistically significantly better overall diagnostic performance.

BUS enables the accurate bedside diagnosis of numerous diseases, such as ectopic pregnancy, thoracoabdominal trauma, pericardial effusion, abdominal aortic aneurysm, cardiac arrest, renal tract disease, and biliary tract disease, as well as procedures such as arthrocentesis, lumbar puncture, and central venous access, with high sensitivity and specificity [11,12].

BUS performed by EPs is advantageous even in busy emergency departments. It facilitates faster assessment and patient management decisions by EPs, reduces the burden on the emergency department radiology department, and shortens the duration of emergency department visits [13].

Additional benefits of the BUS technique include its non-invasive nature, absence of exposure to ionising radiation, and cost-effectiveness [14].

Ultrasonography has been useful in distinguishing acute abdominal pain and related disorders in numerous studies evaluating the effectiveness of BUS performed by EPs in different pathologies [15,16]. EM and radiology specialists correctly diagnosed AA by evaluating abdominal ultrasound to demonstrate the absence of compressibility in a tube-like formation, larger than 6 mm in diameter, and non-mobile, detected in the right lower abdominal quadrant. Our results are similar to those of these studies [15,17].

Hasani and colleagues found that the sensitivity of ultrasound in diagnosing AA was 33.3% (9/27) for EPs and 59.2% (16/27) for radiologists [15]. Although the sensitivity of EPs was lower than in our results, radiologists' ultrasonography was found to be statistically superior in diagnosing AA. The lower sensitivity of EPs performing BUS may be explained by limited practical training opportunities in education programs. The higher sensitivity of EMUS demonstrates its potential value as a screening tool in the emergency department, particularly for ruling out appendicitis in low-risk patients. However, the lower specificity indicates that positive EMUS findings require careful interpretation and may necessitate confirmation through additional imaging or specialist consultation. Although moderate inter-observer agreement (p=0.455) is reasonable, it indicates significant differences in interpretation [18].

Limitations

The limitation of our study is that it is a single-centre study; therefore, the number of patients included is small.

Conclusion

EMUS demonstrates reasonable diagnostic performance for acute appendicitis and can serve as a valuable screening tool in emergency departments. While RUS maintains superior specificity and overall accuracy, EMUS's higher sensitivity makes it useful for initial assessment and triage decisions. The implementation of EMUS may shorten diagnostic time, reduce radiation exposure, and improve patient flow in busy emergency departments.

Conflict of Interests
The authors declare that there is no conflict of interest in the study.

Financial Disclosure
The authors declare that they have received no financial support for the study.

Ethical Approval
The study received ethical approval from the Istanbul Medipol University Non-Interventional Clinical Research Ethics Committee (Approval No: E-10840098-772.02-5414) (Approval Date: 14.10.2021).

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