Diagnostic accuracy of emergency physician performed graded compression ultrasound study in acute appendicitis: a prospective study

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Abstract

Purpose Accurate early diagnosis of appendicitis can decrease its complications and minimize the mortality, morbidity and costs. This prospective study evaluates the accuracy of bedside emergency physician performed ultrasound study diagnosis in acute appendicitis.

Methods Patients who were suspicious to have appendicitis based on their clinical findings were included and underwent emergency physician performed ultrasound study. Then they were followed up until the recognition of final diagnosis based on pathology report or identification of an alternative diagnosis. Ultrasound studies were done by post-graduate year three emergency medicine residents or emergency medicine attending physicians who were attended in a 4 h didactic and practical course and with 7.5 MHz linear probe both in longitudinal and axial axes.

Results Ninety-seven patients were included and analyzed. 27 (27.8 %) of patients had appendicitis according to the results of emergency physicians performed ultrasound studies. 19 (70.37 %) of them had appendicitis according to their pathologic reports too. Forty-three (44.3 %) of patients had appendicitis according to pathology reports. Only 19 (44.18 %) of them were diagnosed by

emergency physicians. Emergency physician performed ultrasound study had a sensitivity of 44.18 %, specificity of 85.18 %, positive predictive value of 70.37 %, negative predictive value of 65.71 % and overall accuracy of 67.01 % in diagnosing appendicitis in patients clinically suspicious to have acute appendicitis.

Conclusion Emergency physician performed bedside ultrasound has an acceptable overall accuracy but its sensitivity is low thus it can help emergency physicians to diagnose the acute appendicitis when used in conjunction with other clinical and para-clinical evaluations but not per se.

Keywords Accuracy · Emergency physician performed ultrasound · Appendicitis · Diagnosis

Riassunto

Scopo Un'accurata diagnosi precoce di appendicite può diminuirne le complicanze e ridurre al minimo mortalità, morbidità e costi. Questo studio prospettico valuta l'accuratezza della diagnosi ecografica, eseguita in emergenza da un medico, nello studio di appendicite acuta.

Metodi Sono stati inclusi i pazienti con sospetto clinico di appendicite e sottoposti ad ecografia d'emergenza eseguita da un medico. I pazienti sono stati poi seguiti fino alla diagnosi definitiva, basata su reperti di anatomia patologica o su una diagnosi alternativa. Le ecografie sono state eseguite da residents di medicina con 3 anni post-laurea o da medici di medicina d'urgenza che avevano partecipato ad un corso didattico e pratico di 4 ore, con sonda lineare da 7.5 MHz sia con scansioni longitudinali che assiali.

Risultati Sono stati inclusi ed esaminati novantasette pazienti. 27 (27,8 %) secondo i risultati delle ecografie effettuate dai medici di emergenza avevano un'appendicite. 19 (70.37 %) di loro avevano un'appendicite anche

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secondo i risultati dell'anatomia patologica. 43 (44,3 %) pazienti avevano un'appendicite, secondo i risultati dell'anatomia patologica. Solo in 19 (44.18 %) di loro era stata diagnosticata dai medici di emergenza. Lo studio ecografico aveva sensibilità del 44.18 %, specificità del 85.18 %, valore predittivo positivo del 70.37 %, valore predittivo negativo del 65,71 % e accuratezza complessiva del 67.01 % nella diagnosi di appendicite in pazienti clinicamente sospetti per appendicite acuta.

Conclusione L'ecografia eseguita da un medico di emergenza ha un'accuratezza complessiva accettabile, ma la sua sensibilità è bassa, quindi può aiutare i medici a diagnosticare in emergenza l'appendicite acuta se usata in combinazione con altre valutazioni cliniche e para-cliniche, ma non se esclusiva ed isolata.

Introduction

Accurate definitive diagnosis of acute appendicitis, the most common abdominal emergency surgery, has been always challenging because of its non-specific symptoms, signs and laboratory findings which can mimic several other pathologies (from a viral gastroenteritis to a complicated ovarian pathology), especially in young women, children and elder patients [1]. Delayed diagnosis may lead to necrosis and perforation of inflamed appendix lumen leading to increased mortality and morbidity. Although with significant improvements in quality and availability of imaging techniques, accurate diagnosis of acute appendicitis has increased in recent years but negative appendectomy still remains a concern, with a rate of 3.7–13.5 % in children [2, 3] and about 12 % in adults [4], imposing additional risks and costs both to patients and health system.

Computed tomography (CT) scan, which is considered the gold standard in diagnosing acute appendicitis exposes patients to ionizing radiation, is expensive and time-consuming and has its own diagnostic insufficiencies [5]. Point-of-care ultrasound study is used as a part of standard care in some patients by acute care physicians including emergency physicians, surgeons, pediatrics and intensive care specialists and alleviates the needs to transfer patients to radiology department. Although bedside ultrasound study can be a less expensive, more rapid, safe alternative for CT scan in diagnosing acute appendicitis, which helps to save CT scan for more complex and confusing cases [6], it is innately an operator-dependent procedure making the knowledge and skill of operator to be the core elements determining its final diagnostic accuracy.

This prospective study evaluates the diagnostic accuracy of bedside emergency physician performed ultrasound in

acute appendicitis in patients clinically suspicious to have acute appendicitis.

Methods

Study design and setting

This prospective multi-center study was conducted in three tertiary-level teaching hospital emergency departments with annual censuses between 40,000 and 70,000 patients. We enrolled cases from May 2013–April 2014 conveniently. Institutional ethics committee (faculty of medicine, Iran University of Medical Sciences) approved our study which was carried out in accordance with Declaration of Helsinki (1989). Informed written consent was obtained from all patients. In patients less than 18 years old, informed written consent was obtained from the parents or legal guardians.

Participants

Patients at any age who had been visited and examined by emergency physician and/or surgeons and whose primary diagnostic impression according to history and physical examination was acute appendicitis were eligible to participate in study. We excluded pregnant women, patients who was evaluated and referred to our hospital with a diagnosed pathology including patients with a positive ultrasound report for appendicitis or ovarian cyst complication, patients with known opium, substance or alcohol addiction, patients with any indication for immediate therapeutic intervention including patients with hemodynamic instability, patients with abdominal mass or guarding in physical examination.

Intervention

History taking and physical examination were done by post-graduate year 1 and 2 emergency medicine residents. Physical examinations were rechecked with emergency medicine attending physicians in doubtful cases. Patients who were suspicious to have acute appendicitis according to their clinical findings were assessed for eligibility. Included patients underwent bedside ultrasound studies performed by post-graduate year 3 emergency medicine residents or emergency medicine attending physicians who use ultrasound studies in their daily practice as e-FAST exam and had attended in a 4-h didactic and practical course about sonographic findings in patients with right quadrat pain including acute appendicitis, ovarian pathologies, urinary pathologies (renal stones) and etc. Result of sonographic evaluation was documented as positive or

negative for acute appendicitis. Patients who had pathologies other than acute appendicitis were also reported as “negative for appendicitis” but the primary impression was recorded in the documents. Patients were followed up until final disposition. In patients who were transported to operation room, the pathology report was considered as diagnostic gold standard. In patients who were not transported to operation room, final diagnosis was considered gold standard. Final diagnosis was defined as the discharge diagnosis for patients in whom an alternative diagnosis was found and treated and as the diagnosis found in complementary evaluations done after discharge or leaving our emergency department.

Ultrasound protocol

Patients were evaluated in supine position. Graded compression ultrasound study of the right lower quadrant was performed with SonoAce X8 (Medison, South Korea) equipment and high-resolution 7.5 MHz linear-array probe by placing the probe on anterior abdominal wall over the site of maximal tenderness in the right lower quadrant compressing gradually (to displace the bowel gas and fluid) with intermittent relief (to avoid causing peritoneal tenderness to find proximal right (ascending) colon) then proceeding inferiorly to the cecum tip and terminal ileum. Ascending colon is a non-peristaltic lumen containing gas and fluid. Terminal ileum is a peristaltic compressible lumen without haustra. The appendix is located in the cecum tip approximately 1 cm below the terminal ileum anterior to psoas muscle and iliac vessels. Scans were done both in longitudinal and axial axes. Retrocecal appendix was searched by oblique angulation of probe and scanning laterally through the flank.

Result was considered “positive for appendicitis” if a non-compressible blind-ended tubular structure with antero-posterior outer wall to outer wall measurement consistently 7 mm or more and without normal peristaltic movements was visualized in right lower quadrant of abdomen in longitudinal axis. The result was also considered positive if an appendicolith (bright echogenic foci with distal acoustic shadow) was found within appendix lumen (with any size). Target appearance in axial section, probe tenderness, distinct appendicular wall layers (laminated walls), increased echogenicity of the peri-appendicular fat and free fluid especially peri-appendicular fluid collection, increased circumferential flow in the wall of the appendix (due to inflammation induced hyper-vascularity) were also suggestive of acute appendicitis which could help sonographer to decide about the diagnosis.

Result was considered “negative for appendicitis” if appendix was not visualized at all (normal appendix cannot be seen in most cases) or if visualized it was a quite mobile

tube with an antero-posterior outer wall to outer wall measurement of 6 mm or less and normal with or without alternative diagnosis.

Data analysis

Descriptive data are reported as mean ($\pm$ standard deviation), maximum and minimum. Categorical data are presented with percentages and 95 % confidence intervals. Sensitivity, specificity, positive and negative predictive values, positive and negative likelihood ratios are calculated. All data analyses were performed with SPSS version 18 (SPSS, Inc., Chicago, IL).

Results

One hundred and twenty patients were assessed for eligibility. One patient had guarding in his physical examination, four patients were referred with a diagnosed abdominal pathology, six patients had drug/alcohol/substance, two patients needed immediate care/surgery, four patients were pregnant, and six patients refused to participate in study. Ninety-seven patients were enrolled in study.

Mean age of patients was 34.35 ($\pm$ 14.90) years old with a minimum of 9 and maximum of 82 years old. Nine (9.2 %) of patients were <18 years old. Seven (7.2 %) patients were >65 years old. Forty-one (42.3 %) of patients were female, and 56 (57.7 %) were male. Most patients (65.9 %) were between 20 and 40 years old. Other baseline data are summarized in Table 1.

Twenty-seven (27.8 %) of patients had acute appendicitis according to emergency physicians performed ultrasound studies. Nineteen (70.37 %) of these 27 patients had appendicitis according to their pathologic reports too. Three (11.11 %) of these 27 patients had urinary pathologies, 2 (7.40 %) had bowel and intestine pathologies and 2 (7.40 %) had non-specific abdominal pain according to their final diagnosis. Forty-three (44.3 %) of patients had acute appendicitis according to pathology reports. Nineteen (44.18 %) of these 43 patients were diagnosed in emergency physician performed ultrasound studies. Thirty-six patients had non-specific abdominal pain, and in 34 (94.4 %) of them, the EPUS was reported as “normal”. Seven patients had gynecologic pathologies. Just one of these seven patients was correctly diagnosed in emergency physician performed ultrasound study. Data about ultrasound findings are summarized in Table 2.

EPUS had sensitivity of 44.18, specificity of 85.18, positive predictive value of 70.37, negative predictive value of 65.71 and accuracy of 67.01 in diagnosing acute

Table 1 Baseline history and physical examination derived data

Variable	Frequency
Frequency of complaints, NO (%)	
Abdominal pain	90 (92.78)
Epigastric	19 (19.58)
Peri-umbilical	22 (22.68)
Right lower quadrant	36 (37.11)
Generalized	19 (19.58)
Anorexia	50 (51.54)
Nausea	50 (51.54)
Vomiting	16 (16.49)
Fever and chills	9 (9.27)
Urologic symptoms	18 (18.55)
Gynecologic symptoms	12 (12.37)
Physical exam findings, NO (%)	
Right lower quadrant tenderness	90 (92.78)
Right lower quadrant rebound tenderness	50 (51.54)
Generalized tenderness	12 (12.37)
Costovertebral angle tenderness	3 (0.03)
Guarding	1 (0.01)
Rovsing's sign ^a	12 (12.37)
Obturator sign ^b	22 (22.68)
Psoas sign ^c	18 (18.55)
Dunphy's sign ^d	25 (25.77)
Fever	8 (8.24)
Tachycardia	25 (25.77)
Tachypnea	36 (37.11)
Past medical history, NO (%)	
Ovarian cyst	12 (12.37)
Diabetes mellitus	8 (8.24)
Hypertension	12 (12.37)
Ischemic heart disease	10 (10.30)
History of renal stones	8 (8.24)
History of cholelithiasis	13 (13.40)
History of GI cancers	3 (0.03)
No remarkable past medical history	50 (51.54)

^a pain in right lower quadrant with palpation of left lower quadrant, ^b pain on internal rotation of right thigh, ^c pain on extension of right thigh, ^d increased pain with coughing

appendicitis in comparison with pathology results and final alternative diagnosis.

Discussion

Our study showed that EPUS has an overall accuracy of 67 % in diagnosing acute appendicitis in patients who are clinically suspicious to have acute appendicitis (according to their clinical findings in history and physical examination). Sensitivity of EPUS was as low as 44 % in our study

Table 2 Frequency of ultrasound findings and diagnoses

Variable	Frequency
Ultrasound findings, NO (%)	
Probe tenderness	75 (77.31)
Non-compressible loop	20 (20.61)
≥7 mm diameter	27 (27.83)
Appendicolith	1 (0.01)
Target appearance	13 (13.40)
Laminated walls	13 (13.40)
Peri-appendicular free fluid	3 (0.03)
Echogenicity appendicular fat	3 (0.03)
Ultrasound diagnosis, NO (%)	
Normal	66 (68.04)
Appendicitis	27 (27.83)
Gynecologic pathologies	1 (0.01)
Other pathologies	3 (0.03)
Final diagnosis, NO (%)	
Non-specific abdominal pain	36 (37.1)
Acute appendicitis	43 (44.3)
Gynecologic pathologies	7 (7.2)
Intestine and bowel pathologies	4 (4.1)
Urinary tract pathologies	7 (7.2)

which shows that EPUS cannot accurately identify the patients with acute appendicitis while relatively high specificity shows its acceptable accuracy identifying the subjects without acute appendicitis. Positive predictive value of EPUS is a little bit higher than its negative predictive value but both of them are in acceptable range which shows that EPUS can help emergency physicians to help acute appendicitis by bedside sonographic evaluation.

Emergency physicians are increasingly become familiar with different applications of bedside ultrasound studies which can help them to make more timely decisions and fasten the patient throughput in emergency departments. One of these new applications is bedside EPUS in diagnosis of acute appendicitis. This is while the diagnostic accuracy of radiologist performed ultrasound study in diagnosis of acute appendicitis still remains conflicting and indistinct, and different studies show different results. As Terasawa et al. showed in their review on 14 studies that ultrasonography has a sensitivity of 86 %, specificity of 81 %, positive predictive value of 84 % and a negative predictive value of 85 % in diagnosing acute appendicitis in patients with right lower quadrant pain and suspicious to have acute appendicitis [7], a large meta-analysis (including 22 articles) in Korea found also a sensitivity of 87 % and specificity of 90 % for sonography in acute appendicitis and another review by Pinto et al. showed also the acceptable overall accuracy for ultrasound study in

diagnosis of acute appendicitis [8]. But there are other studies showing positive predictive value ranging from 46 to 95 % and the negative predictive value ranging from 60 to 97 % for this diagnostic imaging modality [9–13]. The results in children are also inconsistent as the reported sensitivity and specificity in children varies from 44 to 100 % and 47 to 99 %, respectively [14–17].

There are limited studies focusing specifically on emergency physician performed ultrasound study. For example, Fox et al. studied 132 emergency department patients clinically suspicious to acute appendicitis by bedside ultrasound and showed sensitivity of 65 %, specificity of 90 %, positive predictive value of 84 % and negative predictive value of 76 % which is compatible with our study results [18]. There is also a case series of young women which shows that point-of-care vaginal ultrasound can help to make rapid and safe evaluation and disposition in women with right lower quadrant pain [19].

In our study, sensitivity of EPUS was as low as 44 % which means that a significant number of patients with acute appendicitis have been missed by emergency physicians based on their sonographic results. Our results show that emergency physicians were not accurate enough in measuring the diameter of appendicular lumen, a potentially confounding factor in ultrasound interpretation. This may be due to the importance of expertise and steep learning curve in ultrasound application procedures and emergency physicians' inability in measuring the diameter. Another reason may be related to the technique of measurement as some emergency physicians may have measured inner to inner wall of lumen instead of outer-to-outer one. We should not forget the innate shortenings of sonography in diagnosis of acute appendicitis including its limitations in obese patients, pregnant patients, and patients with gassy bowel loops, patients with severe pain/tenderness or guarding, uncooperative patients, patients with distorted anatomy and patients with perforated appendix. Ultrasound has also limited accuracy in detecting pelvic, retrocecal, and retroileal position appendicitis [20–22].

Limitations

Our study was a general assessment of diagnostic accuracy of EPUS in diagnosis of acute appendicitis. Other studies are needed to focus on the application of this modality on different populations (like patients with different age groups, sex, and body mass index), different locations of appendix, with different types of probes and techniques and in emergency physicians with different levels of experience. It would be also helpful if the learning curve of sonographers be drawn. Another field for more studies may

be assessing the accuracy of repeated clinical and/or EPUS studies in diagnosing the acute appendicitis.

Conclusion

Emergency physician performed bedside ultrasound has an acceptable overall accuracy but its sensitivity is low thus it can help emergency physicians to diagnose the acute appendicitis when used in conjunction with other clinical and para-clinical evaluations but not per se.

Conflict of interest The authors (Seyyed Abbas Hasani, Marzieh Fathi, Mohammad Amin Zare, Marzieh Daadpey, Nader Hojati Fir-oozabadi, Daniyal Lotfi) have no conflict of interest.

Human and animal studies The study was conducted in accordance with all institutional and national guidelines for the care and use of laboratory animals.

Informed consent All procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2000 (5). All patients provided written informed consent to enrolment in the study and to the inclusion in this article of information that could potentially lead to their identification.

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