ORIGINAL ARTICLE

DIAGNOSTIC ACCURACY OF ULTRASONOGRAPHY IN ACUTE APPENDICITIS

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Background: The diagnosis of acute appendicitis is mainly clinical and to augment the clinical diagnosis ultrasonography and Computerized Tomographic Scan of the abdomen are also being used to help in diagnosis of the disease; which all carry some inherent limitations. This study was done to establish diagnostic accuracy of Ultrasonography (USG) in acute appendicitis taking histopathology of removed appendix as the gold standard. **Methods:** This cross-sectional validation study was conducted in Radiology Department, Military Hospital and Combined Military Hospital Rawalpindi from July 2007 to January 2008. Sixty cases of clinically suspected acute appendicitis were selected on non-probability convenience sampling technique. All of them underwent ultrasound evaluation. Diagnostic accuracy of USG was calculated keeping histopathology of the removed appendix as gold standard whenever appendectomy was carried out. **Results**: Out of 60 patients whose USG of right lower quadrant was performed, 30 patients were correctly diagnosed as having acute appendicitis on USG out of 34 finally diagnosed cases based on histopathology. Similarly we picked 12 normal appendices out of 26 non-appendicitis patients. This showed that US scan has sensitivity of 88%, specificity of 92%, positive predictive value of 94%, negative predictive value of 86%, and overall accuracy of 90%. The most accurate appendiceal finding for appendicitis was a diameter of 7 mm or larger followed by non-compressibility of inflamed appendix. **Conclusion:** Ultrasonography has high accuracy in diagnosing acute appendicitis and reduces negative appendectomies. Greater than 6-mm diameter of the appendix under compression is the most accurate USG finding with high positive predictive value for the diagnosis of acute appendicitis.

Keywords: Ultrasonography, Appendix, Appendicitis, Appendectomy

J Ayub Med Coll Abbottabad 2014;26(1):12–7

INTRODUCTION

Acute appendicitis is one of the commonest acute surgical conditions.[1] Although great advances have been made in diagnostic modalities, yet the surgeon's clinical acumen is put to test in almost 30–40% cases which raises the rate of negative appendectomies to around 20% and carries both the risks of mortality and morbidity.[2] Its accurate clinical diagnosis is still not possible due to atypical clinical presentations, which are quite common as many inflammatory and non-inflammatory conditions simulate the clinical picture of the disease. These errors in diagnosis commonly occur in women belonging to reproductive age group[3] and patients in the extremes of age.[4] Above all the clinical scenario and USG is more perplexed by the variation in anatomical positions of the organ.

The major part in diagnosis of acute appendicitis is made by the patient's history, physical examination along with few supportive investigations like the Total Leucocyte Count (TLC). Also scoring systems like Alvarado[3], Ohmann and Eskelinen score have been devised to achieve more accuracy in diagnosis. Apart from that Ultrasonography (USG) and Computerized Tomographic Scan (CT scan) of the abdomen are also being used to help in diagnosis of the disease; which all carry some inherent limitations.

Inflammatory marker C-reactive protein (CRP), produced by hepatocytes indicating acute inflammation is a non-specific test, yet many authors did address and emphasize the accuracy of CRP in diagnosis of acute appendicitis.[5]

Importance of CT scan for diagnosing acute appendicitis is advocated. Many studies carried out on the subject have claimed negative predictive value of around 98%.[6] It has also been advocated that since the investigation is not operator dependent, thus chance of variation in results among different centres is very less. Although we cannot deny the argument made by its supporters, yet we need to consider limitations of our setup. The facility of CT scan is not widely available in our country and carries a high cost for our poor population. Apart from that it also exposes the patient to both extensive radiations and anaphylaxis due to intravenous contrast agents. So there is a dare need to look for a diagnostic tool that not only carries high sensitivity and specificity; but also can provide cheap, fast, and readily available services.

USG of the abdomen is yet another practiced investigation, the principle advantage not its highest accuracy but its non-invasive nature. The diagnostic

sign of acute appendicitis is visualization of appendix on USG. However it failed to gain popularity as a pillar of diagnosis in the disease, because it is very much operator dependent and results varies from person to person depending upon the expertise of the radiologist and also patient factors like obesity, gas filled gut loops in front of the appendix, amount of inflammatory fluid around it, as well as position of the appendix. Studies have also proved that a normal appendix can be visualized in 72% of patients without appendicitis.[6]

USG is a very simple and non-invasive diagnostic test. The results of the test are available to the clinician within 30 minutes with total cost of Pakistani Rupees 400 that is less than the combined cost of full blood count, urine RE and TLC. In addition USG also diagnoses alternate disease conditions. All these characteristics together make it quite favourable and affordable for our patient population.

The significance of this study is that USG will definitely improve general surgeon's confidence in diagnosis of acute appendicitis and reduce the negative appendicectomy rate; thus reducing workload of hospitals and postoperative complications.[7]

The rationale of this study was to add further information and help in better understanding of role of USG, in patients of acute appendicitis. This also highlighted the importance of ultrasound as a useful, readily available, non-invasive and radiation free investigation in these patients. The study was based on the presumption that a thorough appendicitis-specific USG examination yields more accurate diagnosis helping to reduce high negative appendectomy rates and thereby benefiting the affected patients.

MATERIAL AND METHODS

This was a cross-sectional study, with subjects selected through non-probability convenience sampling, conducted at the Department of Radiology, Military Hospital/Combined Military (CMH/MH) Hospital Rawalpindi from July 2007 to Jan 2008. Sixty patients of all ages and either gender with clinically suspected acute appendicitis were referred to Department of Radiology, CMH/MH Rawalpindi for USG in the duration of this study. Pregnant patients, patients with adnexal masses and with history of renal stones were excluded on history and any previous investigations. USG abdomen/right lower quadrant was initially performed in all of them using Toshiba Aplio and GE Logic 500 Pro Series machines after taking informed consent in all the cases. Findings of each USG were substantiated by opinion of a consultant radiologist.

In each patient, the abdomen was initially examined by using a 3.5/5.0 MHz convex-array transducer. Sonographic evaluation of appendix and surrounding area was made using 7.5–11 MHz, linear array transducer with graded-compression technique in transverse as well as longitudinal planes. The right psoas major muscle and iliac vessels were visualized with a transverse axial scan. Caecum was then recognized lying over the psoas muscle. Using the above structures as landmarks, visualized appendix was identified as a blind-ending, aperistaltic tubular structure. When the appendix was difficult to identify within an examination time of approximately 15–20 minutes, the most appropriate operator-dependent technique (upward graded compression, posterior manual compression or left oblique lateral decubitus position) was attempted in addition to graded compression for maximum of another 15–20 minutes. Colour Doppler USG to detect blood flow in appendiceal wall was performed at the end of the gray-scale sonography by using a low-velocity scale (pulse repetition frequency, 1,500 Hz) and a low wall filter (100 Hz) to detect slow blood flow.

USG criteria for diagnosing acute appendicitis were grouped into two categories:

1. Appendiceal findings: These findings were noted for their presence or absence in both normal as well as inflamed appendices.
   - Outer diameter: Appendix was considered enlarged and inflamed when its outer antero-posterior diameter under compression, measured in transverse plane, was >6 mm.
   - Lack of compressibility
   - Appendicolith
   - Blood flow in appendiceal wall on colour Doppler
2. Peri-appendiceal findings: These were noted in all patients irrespective of visualization of appendix.
   - Hyperechoic peri-enteric fat in RLQ
   - Cecal wall thickness of 5 mm or more
   - Surrounding fluid or abscess.

In general, USG was considered positive when at least two or more criteria for acute appendicitis were met and negative if a normal looking appendix was visualized or if it was not visualized and/or a definite non-appendicular pathology was noted. The final decision to operate upon was made by the attending surgeon who was aware of laboratory as well as USG findings. Histopathological specimens of appendix obtained through surgery were sent to Armed Forces Institute of Pathology (AFIP) and reports were available in 7 days.

Patients with negative USG findings and those who did not undergo surgery at first place were followed up in respect of clinical and surgical outcomes. We considered histopathology to be the

gold standard for the accurate diagnosis of acute appendicitis; hence for this study the sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV) and accuracy of USG was based on the findings of histopathology. Data was entered into computer package SPSS-11 for statistical analysis. Sensitivity, specificity, positive predictive, negative predictive values and accuracy was calculated using the 2×2 table.

RESULTS

A total of 60 patients who presented with symptoms and signs suggesting acute appendicitis in surgical OPD's and Emergency Departments of CMH and MH Rawalpindi were included in the study. There were 48 (80%) males and 12 (20%) females. The age of the patients ranged from 10 years to 70 years with a mean age of 31.41±12.87. Thirty-two patients were diagnosed as suffering from acute appendicitis on USG and surgery was done in them. Histopathology of their resected appendices showed features of acute appendicitis in 30 thus making them as true positive cases. Two appendices turned out to be normal on histopathology, thus making them false positive USG results.

In 28 patients having normal USG findings; a normal appendix was seen in 12 patients (43% of USG negative patients) and in the remaining 16 (57%); it was not seen on USG. The 28 patients negative on USG were followed up for varying periods till a definite diagnosis was established as shown in Table-2. Four patients, among these 28 USG negative patients, persisted to have clinical signs and symptoms of acute appendicitis whereas 24 patients became asymptomatic or had alternative diagnoses. These 24 cases were labeled as true negative for appendicitis as appendicitis was ruled out in them on USG. In 4 patients having persistent clinical signs and symptoms of acute appendicitis surgical intervention was carried out within 24 hours of USG examination and they turned out to be having inflamed appendices on surgery and histopathology thus making them as false negative cases. One out of these four patients had perforated appendicitis and the other three had retrocecal appendices.

Statistical analysis of our study revealed the following: Sensitivity (88%), Specificity (92%), Positive predictive value (94%), Negative predictive value (86%), and Diagnostic accuracy (90%).

In 26 total negative cases (FP+TN) alternative diagnoses were confirmed on USG in 12 patients, on histopathology in 2 patients (2 USG false positive cases), at laparoscopy in one patient and at clinical follow up in 11 patients.

Surgery and histopathology established final diagnosis of acute appendicitis in 34 out of total 60 patients suspected of acute appendicitis. Among these 34 appendicitis patients, 25 (73.5%) were male and 9 (26.5%) female. USG was able to detect inflamed appendices correctly in 30 (88%) patients having the disease. Appendix was seen on USG in 42 out of 60 patients (70%) including 30 inflamed and 12 normal appendices. In these 42 patients, a diameter of 7 mm or larger was the most accurate finding for appendicitis followed by lack of compressibility. In those patients with appendicitis but having an outer appendiceal diameter less than 7 mm, distal appendicitis was revealed by surgical and pathologic examination, Flow in the appendiceal wall was encountered in patients having diseases other than appendicitis and also in less than half of the patients with appendicitis so it was not a sensitive finding, however it was found to be a specific finding for appendicitis. Appendicolith was found in only 6 (20%) of appendicitis patients.

The peri-appendiceal USG findings were looked for in the entire study group. Fat changes in the right lower abdominal quadrant were present in 26 (87%) of the confirmed acute appendicitis cases. However it was also seen in 4 patients not having acute appendicitis. These included one patient with mesenteric adenitis, one patient with ileocaecal TB, one patient with pelvic inflammatory disease, and one patient with pyelonephritis. Ceacal wall thickening was detected at US in only 6 (20%) of patients with appendicitis. Surrounding fluid was present in 14 (48%) of appendicitis cases. Frequencies of different appendiceal and peri-appendiceal findings are shown in Table-3

Table-1: The outcome of study subjects

USG	Surgical Biopsy		Total
	Positive	Negative	
Positive	TP (30)	FP (2)	32
Negative	FN (4)	TN (24)	28
Total	34	26	60

Table-2: Final diagnoses in these 26 patients.

Diagnosis	No of patients (n=26)
Pain with no definite cause	11
Mesenteric lymphadenopathy	5
PID	3
Urological disease	3
Ileoceacal tuberculosis	1
Gastroenteritis	1
Cystitis	1
peptic ulcer	1

Table-3: Frequencies of different appendiceal and peri-appendiceal findings (n=30)

Finding on Ultrasound	Number	Percentage
Diameter	29	96.7
Non-compressible	28	93.3
Echogenic fat	26	86.7
Surrounding fluid	14	46.7
Flow in wall	14	46.7
Appendicolith	6	20
Caecal thickening	6	20
Appendicular mass	3	10

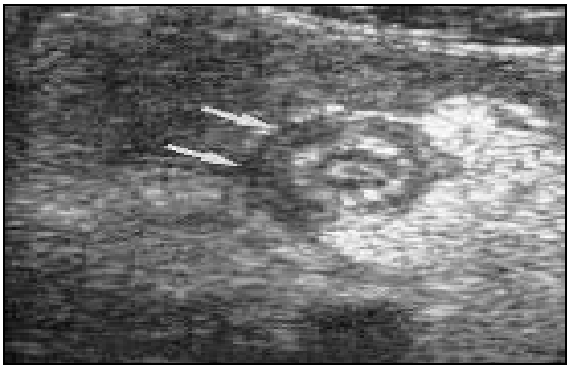

Figure-1: Transverse ultrasounds scan of acute appendicitis
(Note the thickened wall and surrounding fluid collection)

DISCUSSION

It goes without saying that acute appendicitis makes the major bulk of present day emergency abdominal surgery, yet it always puts the surgeon's clinical judgment to a real test. If not all but in majority of cases especially in women, children and old age patients it holds true. Different diagnostic modalities are available for the diagnosis of acute appendicitis at an early stage. TLC, Urine RE, USG and CT scan abdomen are the most effective methods, however none is perfect and all have advantages and disadvantages. It has been suggested that a combination of various diagnostic modalities will give the best results.

Our study showed that appendicitis prevails mostly in young males. There were 70% patients (mostly males) ranging between ages of 21–40 years. The second common group was between 10–20 years. These age and gender statistics are in accordance with local[8] and international studies.[9,10]

We performed USG on the patients using Toshiba Aplio and GE Logic 500 Pro series Doppler USG Machine with 3.0/5.0 MHz convex and 7.5–11 MHz linear probes. Based upon the works of Puylaert *et al*,[11] Baldisserotto *et al*,[12] Yabunaka *et al*,[13] and Lee *et al*,[14] an imaging protocol for USG was standardized. Keeping the psoas muscle, iliac vessels and cecum as anatomical landmarks, appendix was identified in right lower quadrant using the graded compression and operator-dependent techniques.

USG identified 32 patients as having acute appendicitis out of which, two patients had normal appendices on surgery and histopathology showing these two as USG false positive results. Both patients were finally diagnosed as having non-specific abdominal pain. This resulted in the negative appendectomy rate of 6%, which is quite less as compared to that reported in the literature (10–30% and as high as 47% in women of childbearing age) [15,16] when diagnosis was based solely on clinical evaluation.

False negative USG outcomes in our study were four, mainly due to retrocaecal position followed by perforation. Out of these four three patients had retrocaecal appendicitis and one patient had perforated appendicitis. Appendiceal perforation results in luminal decompression and reduced appendiceal diameter resulting in false negative US examinations.[17] With perforation[18] a non-compressible appendix may be identified in only 38–55% of patients. Retrocaecal position or perforation of the appendix is a common cause of appendiceal misdiagnosis on USG.[18]

Out of USG negative patients for acute appendicitis (n=26), 13 patients were diagnosed definitely on USG, including 5 patients with mesenteric lymphadenopathy, 3 female patients with various gynaecological disorders, and 3 with urological diseases. There were probable diagnosis of ileocaecal TB and gut perforation in two patients, which all showed the same diagnosis on follow up. This avidly demonstrated the benefit of US for provision of an alternate diagnosis to explain the patient's symptoms providing the opportunity to examine rest of the abdomen and pelvis in a very short acquisition time.[18]

There are certain parameters for USG diagnosis of acute appendicitis out of which the outer diameter of the vermiform appendix is the most important diagnostic criterion in the evaluation of acute appendicitis, with the most sensitive and specific being a diameter of 7 mm or greater (sensitivity, 98%; specificity, 98%), lack of compressibility (sensitivity 96%; specificity 98%), and inflammatory fat changes (sensitivity 91%; specificity 76%).[12]

In our study, the most accurate diagnostic USG criterion was a diameter of 7 mm or greater with a sensitivity of 97% (NPV of 93% and high PPV of 97%) but it do show false positive results. So we need another ultrasound criterion of acute appendicitis having similar or nearer diagnostic values. In this regard, lack of compressibility of appendix is another finding with high PPV (93%) and sensitivity (85%).

We found 87% sensitivity in our study for inflamed fat which is 100% sensitive but not a specific sign of appendicitis at CT.[19] Inflamed fat in the right lower quadrant may be present in a broad spectrum of alternative diagnoses to appendicitis. Inflamed fat was not detected in every patient with appendicitis, contrary to known data from CT studies, which show that some subtle inflammatory changes may have been missed in USG assessment. We did not analyze the non-compressibility of the fat, which could be an interesting finding for diagnosing inflamed fat.

We found that hyperemia in the appendiceal wall shown on Colour Doppler images was a specific finding for appendicitis. This finding, however,

showed a sensitivity of only 46%.

Due to limitation of adequate Ceacal distention we limited our evaluation with USG to the identification of ceacal wall thickening, which showed 46% sensitivity in our study.

Other rare signs in our study such as fluid surrounding the inflamed appendix, appendicolith and appendicular mass showed sensitivities of 46%, 17% and 10% respectively.

The nonvisualized normal appendix presents a serious limitation to confident exclusion of acute appendicitis.[16] Yabunaka *et al*[14] had achieved the same up to 49.2% appendix visualization in healthy population using the latest tissue harmonic imaging Our study results (43% of the non-appendicitis patients) are nearly similar to it. Our study also showed a NPV of 75% in appendicitis-suspicious patients.

We recommend that in patients whose appendix is not visualized at USG, laboratory tests could be performed to strengthen the NPV of non-visualization of the appendix or in terms of equivocal findings and non-elevated WBC, USG may be a useful adjunct to clinical and laboratory evaluations, which is also the view of the surgeons surveyed. However, further studies that include more patients in whom the appendix is not identified at USG are necessary to confirm this potential role of laboratory tests.

Although obesity is a well-recognized factor that severely limits the performance and interpretation of any USG examination, it may also hinder the physical examination, leading to diagnostic uncertainty. This factor would probably influence the surgeon to request USG, even if USG is known to be of low prognostic value. CT would be the preferred imaging method in this case; however, at our institution, CT for appendicitis is used only as a problem-solving tool because we have only one CT scanner and the cost of CT scan is high.

USG is inexpensive, non-invasive, rapid, and requires no patient preparation or contrast material administration and there is no radiation exposure, so it must be performed in all cases and CT scan should be reserved for unresolved cases or doubtful cases of acute appendicitis.

Important limitations of USG are that it is operator-dependent, it can be difficult to perform in patients with severe abdominal pain or in patients with large amounts of bowel gas, and it can be limited in muscular or obese patients, in patients with poorly defined right lower quadrant anatomy, and in patients with a retrocecal or perforated appendix.

The most fundamental finding of our study is that it establishes USG scan being accurate and highly specific in diagnosing acute appendicitis. This is in accordance with most studies carried out to date.[20]

Our study has certain clinical applications. Firstly USG scan must be used whenever there is suspicion of appendicitis with equivocal findings and this should be performed earlier without delaying as appendicitis can lead to perforation and other related complications. This will definitely reduce the negative appendectomy rates and reduce burden on hospital resources. Secondly, there is need to improve level of skill of radiologists as it is highly operator dependent. Thirdly, we need to conduct a study on larger scale in patient groups so as to find out the best technique that can be used as a standard protocol for the diagnosis of acute appendicitis.

We also recommend larger sample size studies of longer durations (at least 3–5 years) to establish the cost-effectiveness of USG on the outcome of patients with acute appendicitis.

Finally, an autonomous utilization inside the surgical unit, of a low cost and rapid diagnostic method like USG, able to avoid unnecessary surgical interventions, can lead to an important cost saving. To summarize, our study suggests a quick protocol to diagnose acute appendicitis especially in equivocal cases with cost effectiveness, avoiding radiation exposure and intravenous contrast administration.

CONCLUSION

Ultrasound is a non-invasive highly diagnostic investigation that has improved our ability to detect appendicitis and its complications with improved results and reduced rate of unnecessary surgeries. Tissue harmonic ultrasound therefore is an imaging modality of preference in cases of acute appendicitis. Diameter of larger than 6 mm is the most sensitive US finding for appendicitis, with high PPV and NPV, followed by non-compressibility of the inflamed appendix. These two US findings together provide the most accurate diagnosis in suspected cases of acute appendicitis.

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