

Ultrasound Evaluation of Suspected Appendicitis

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Summary:

Background To evaluate the sensitivity, specificity, accuracy, positive predictive value (PPV), and negative predictive value (NPV) of ultrasonographic and doppler US findings in the diagnosis of acute appendicitis.

Method : A total of 115 cases of clinically suspected appendicitis were prospectively examined by grey scale US and doppler US. Five patients were excluded from the study because of difficulty to perform the graded compression technique. In the other 115 patients who were included in the study population, US appendiceal and periappendiceal signs, as well as doppler US findings were evaluated. Definitive diagnosis was established at surgery and histopathological examination in 62 patients (59 patients with appendicitis & 3 patients with alternative final diagnosis), and at clinical follow up in 48 patients.

Results : The prevalence of appendicitis in this study was 54%. The appendix was identified in 80 (73 %) of the 110 patients, which included 55 (93 %) of 59 patients with appendicitis & 25 (94.9 %) of 51 patients without appendicitis. The most accurate appendiceal finding for appendicitis was a diameter of ≥ 6 mm & non compressibility, which both had an accuracy of 96 %. The lack of visualization of the appendix had a NPV of 87 %, while the visualization of a normal appendix with a diameter of < 6 mm had a NPV of 96 %. Inflammatory periappendiceal fat changes had a sensitivity of 92 %, PPV of 83 %, & a NPV of 89 %. Hyperaemia in the appendiceal wall, although had a low sensitivity (53%), it had both high specificity (92 %) & high PPV (94 %). The other findings had both low PPV & NPV.

Conclusion : A non compressible appendix with a threshold outer diameter of 6 mm under compression is the most accurate US finding for appendicitis; with high sensitivity, specificity, PPV, & NPV.

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Introduction:

The clinical diagnosis of acute appendicitis has approximately 20% false positive and 20% false negative error rate [1-5]. When a patient presents with typical symptoms and signs of appendicitis, the diagnosis is usually straightforward. However, approximately 20-30 % of patients suspected of having acute appendicitis will present with equivocal clinical findings &/ or laboratory test results [3,6].

To reduce the error rate in the diagnosis of this potentially life threatening condition, diagnostic imaging is playing an increasing role including CT scanning with and without contrast material administered via different routes [7,8,9].

Since its introduction by Puylaert in 1986 [10], graded compression US has been the mainstay of imaging in suspected appendicitis. Although US criteria for the diagnosis of acute appendicitis has been well described, and high sensitivity & specificity values has been published [11,12], these

values seem to be highly operator or institution dependant. Furthermore, the location of the appendix is unpredictable. It may be found in a retrocecal, pelvic, subcecal, preileal, or postileal location [13]; often making it very difficult for the sonographer to identify & image the appendix in its entirety.

Many believe that the main disadvantage of graded compression US in suspected appendicitis is the infrequency with which the normal appendix can be visualized [14]. Thus, many radiologists & clinicians think that an US examination in which the appendix is not identified does not reliably exclude early appendicitis.

Reported US criteria of acute appendicitis can be grouped into two categories: (a) appendiceal findings, and (b) periappendiceal findings which mainly include inflammatory changes in the right lower quadrant. Many US signs are present in most cases of suspected appendicitis [15,16]. Some of these signs, however, are also present in alternative conditions that can clinically mimic acute appendicitis.

Aim of the study

To evaluate the sensitivity, specificity, positive predictive value (PPV), negative predictive value

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(NPV), and accuracy of the individual US signs, & doppler US in the diagnosis of appendicitis.

Patients and methods

Study population

From May 2004 to February 2006, 115 cases of clinically suspected acute appendicitis were examined prospectively by trans abdominal US for signs of appendicitis. The study group include patients aged 14- 76 years (mean age 27 years) & consisted of 75 female patients & 40 male patients.

US Technique

All US examinations were performed by two experienced radiologists in consensus. In each patient, the abdomen was initially examined using the available Seimens high resolution real- time machines utilizing 3.5 MHz convex array transducer supplemented with US assessment of the appendix and the surrounding region using a 7.5 MHz linear array transducer.

The graded compression technique (applying compression in a graded manner to avoid pain) described by Puylaert [14 I] was used to detect the vermiform appendix. All patients were routinely asked to point to the site of maximal pain in the right lower quadrant (RLQ) with a single finger. Scanning of this area was often helpful in identification of aberrantly located appendix. The examination was initiated by scanning in the transverse plain in the lateral right midabdomen just above the level of the umbilicus. The examination was continued caudally in the right lower quadrant with gradually increasing compression. Compression was increased until all bowel gas & /or fluid could be expressed from the ascending colon & cecum. An attempt was made to image the cecal tip in the transverse plane by scanning caudad to the approximate insertion of the terminal ileum. Gently reducing and then increasing the pressure of the transducer readily allowed assessment of compressibility of the normal bowel. The normal cecum and terminal ileum could easily be compressed with moderate pressure.

Color Doppler US was performed at the end of the gray scale US examination using optimized color doppler parameters. These parameters were set at a low wall filter (100 Hz), low - velocity scale (pulse repetition frequency of 1500 Hz) to detect slow blood flow of (0.09 m/sec.). color gain was adjusted dynamically to maximize visualization of blood vessels while avoiding artifactual color noise that results from peristaltic movement of the bowel. At these settings, normal appendices & periappendiceal tissues showed no color signal.

Pulsed doppler waveforms were routinely obtained when color signals were seen.

Interpretation

The presence or absence of the following criteria in each patient was evaluated :

1. An enlarged appendix (blind ending tubular structure with an outer diameter of ≥ 6 mm under compression).
2. Fluid in & or absence of gas in the appendiceal lumen.
3. lack of compressibility of the appendix.
4. inflammatory changes in the periappendiceal fat (hyper echoic halo surrounding the distal ileal wall, cecum, or appendix).
5. cecal wall thickening (5 mm or more from the outer wall to the luminal surface under compression).
6. Right lower quadrant lymph nodes (5 mm or more in the smallest diameter).
7. Peritoneal fluid.
8. Color in the appendiceal wall on color doppler US.

The final diagnosis was based on surgical and histopathological results in surgically managed cases, or by follow up in non surgically managed cases.

Statistical Analysis

The sensitivity, specificity, accuracy, PPV, & NPV of each appendiceal US sign, periappendiceal US sign, & doppler US finding in the diagnosis of acute appendicitis were calculated.

Results

Of the 115 patients with clinically suspected appendicitis, the graded compression technique could not be properly done due to intolerance to the examination because of severe tenderness in 3 patients & obesity in the other two patients, these 5 patients were excluded from the study.

Of the remaining 110 patients who were included in the study, 59 patients proved to have appendicitis at final diagnosis (prevalence of appendicitis was 54 %) & 51 patients didn't have appendicitis. In all the 59 patients with acute appendicitis, the final diagnosis was established by surgery and histopathological examination. In this group, surgical findings showed appendiceal perforation in 3 patients.

Among the 51 patients without appendicitis, the final diagnosis was performed by surgery in 3 patients & by follow up in 48 patients. Table 1 lists the final diagnosis established in the non appendicitis group.

Table 1 : Final diagnosis in 51 patients without appendicitis.

Final diagnosis	No. of patients
Non specific abdominal pain	15
Gynecological disease	11
Mesenteric adenitis	10
Gastroenteritis	8
Colitis	3
Pyelonephritis	2
Gastric ulcer	1
Cystitis	1

Appendiceal identification : the appendix was identified at US in 55 (93%) of 59 patients with a final diagnosis of acute appendicitis, whereas it was identified in only 25 (49%) of the 51 patients with a final diagnosis of not appendicitis. Thus the appendix was identified in 80 patients & not identified in 30 patients of the study population.

Of these 30 patients in whom the appendix was not identified, 4 had a final diagnosis of appendicitis (three of them were found to have perforation at surgery & one had non perforated appendicitis), & 26 had a final diagnosis of not

appendicitis. Thus giving the lack of visualization of the appendix a NPP of 87 % .

The 80 patients in whom the appendix was visualized, constituted a group in which **appendiceal US findings** could be tested.

Table 2 shows : (1) the frequency with which each appendiceal finding was interpreted as positive or negative; (2) the number of true positive, true negative, false positive, & false negative results; &(3) the sensitivity, specificity, accuracy, PPV, & NPV of each appendiceal finding.

Table 2 : Appendiceal US & doppler US findings in 80 patients in whom the appendix could be visualized at US.

Finding & value	diameter \geq 6 mm	lack of compressibility	intra luminal fluid & or absence of air	flow in the wall on color doppler
(1) Finding at US				
positive	56	56	36	31
negative	24	24	44	49
(2) Finding at final diagnosis				
True-positive	54	54	33	29
True-negative	23	23	22	23
False-positive	2	2	3	2
False-negative	1	1	22	26
(3) Value				
sensitivity	98 %	98 %	60 %	53 %
Specificity	92 %	92 %	88 %	92 %
PPV	96 %	96 %	92 %	94 %
NPV	96 %	96 %	50 %	47 %
Accuracy	96 %	96 %	69 %	65 %
Note : unless otherwise noted, data represent numbers of patients				

The two most accurate appendiceal findings for appendicitis were a *diameter \geq 6mm*, & *lack of compressibility*, with an accuracy of 96 % for both. Of the 55 patients with visualized appendix in the group with a final diagnosis of appendicitis, 54 patients had an appendiceal diameter of \geq 6 mm and only one patient with a final diagnosis of acute appendicitis had an appendiceal outer diameter of less than 6 mm.

Among the 25 patients with visualized appendix in the non appendicitis group, the appendiceal outer diameter was $<$ 6mm in 23 patients & \geq 6 mm in only 2 patients, one with a final diagnosis of pyelonephritis, and one with a final diagnosis of mesenteric adenitis. Thus, an appendix with a diameter \geq 6 mm was found in 56 patients [54 patients with a final diagnosis of appendicitis (true positive), & 2 patients with a final diagnosis of not appendicitis (false positive)]. While an appendix

with a diameter of < 6 mm was found in 24 patients [23 patients with a final diagnosis of not appendicitis (true negative) , and one with a final diagnosis of appendicitis (false negative)] , giving the visualization of a normal appendix with a diameter of < 6 mm a NPV of 96 %.

Fluid in &/ or absence of gas in the appendiceal lumen was specific for appendicitis, with a specificity of (88 %); however, this finding was not

sensitive since it was encountered in only 60 % of patients with appendicitis.

The same applies for *flow in the appendiceal wall* which showed a specificity of (92 %) but only a sensitivity of (53 %).

The *peri appendiceal US findings* were tested in the entire study population of 110 patients(in the 80 patients with visualized appendix & in the 30 patients with non visualized appendix). Table 3 lists these findings.

Table 3 : periappendiceal US findings in 110 patients.

Finding & Value	Inflammatory fat changes	Cecal wall thickening nodes	peri-ileal lymph	peritoneal fluid
(!)Finding at US				
Positive	65	21	40	44
Negative	45	89	70	66
(2)Finding at final Diagnosis				
True-positive	54	15	19	30
True-negative	40	45	30	37
False-positive	11	6	21	14
False-negative	5	44	40	29
(3)Value				
Sensitivity	92 %	25 %	32 %	52 %
Specificity	78 %	88 %	59 %	73 %
PPV	83 %	71 %	48 %	68 %
NPV	89 %	51 %	43 %	56 %
Accuracy	85 %	55 %	45 %	61 %
Note : unless otherwise noted, data represent numbers of patients				

Inflammatory changes in the peri appendiceal fat were present in 54 (92 %) of the 59 patients with appendicitis but also in 11(22 %) of the 51 patients in the non appendicitis group (which included 5 patients with mesenteric adenitis, , 3 patients with gastroenteritis , two patients with colitis, & one patient with pyelonephritis).

Cecal wall thickening was detected at US in only 15 (25 %) of 59 patients with appendicitis & in 6 (12 %) of 51 patients without appendicitis.

Right lower quadrant adenopathy was present in 19 (32 %) of 59 patients with appendicitis & in 21 (41 %) of 51 patients without appendicitis.

Peritoneal fluid was noted in 30 (51 %) of 59 patients with appendicitis but also in 14 (27%) of 51 patients without appendicitis

Discussion

Appendiceal visualization : in his original description of the graded compression technique, Puylaert [10] in 1986 emphasized that visualization

of the appendix alone was the sole criterion for diagnosis of acute appendicitis by means of US. No " normal " appendices were visualized in that study. Further, the appendix was not visualized in a control group of 50 individuals who had no clear evidence of appendicitis.

One year later, Abu-Yousef et al [17] noted visualization of a " normal " appendix with a thin hypoechoic wall 2 mm thick or less in 2 of 68 patients. Jeffry [18] in 1988 also demonstrated that a histologically normal appendix can be visualized with high resolution US where 5 patients with appendiceal diameter of ≤ 6 mm in his study had either a benign course or a normal appendix removed at surgery and he stated that in the absence of appendicoliths or compelling indications for early laparotomy, close observation rather than surgery is warranted in adults with maximum appendiceal diameter of 6 mm or less. He also stated that in the presence of multiple appendicoliths, early laparotomy is justified even if

the appendicular diameter is relatively "normal " because of the greater risk of gangrenous appendicitis and perforation [19] on account of finding appendicoliths & appendiceal diameter of 6 mm in two patients with pathologically proved appendicitis.

Until 1992, the reported frequency of visualization of the appendix was 0-4% in the adult population [18,20]. Until that time, the inability to visualize a normal appendix at US was classically considered a major drawback of using US in the assessment of suspected appendicitis since it represents a serious limitation to confidently exclude the diagnosis of appendicitis[14].

In 1992, Rioux et al. [12] visualized a normal appendix in 82% of patients without acute appendicitis. Rettenbacher et al. in 1997 [11] visualized a normal appendix in 64 % of a population of healthy subjects.

It seems that increased radiological experience , in addition to technical improvements have improved the ability to visualize a normal appendix. Thus non visualization of the appendix is no longer suggestive of a normal appendix as was previously thought, and a visible appendix is not enough by itself to diagnose acute appendicitis since the normal appendix is frequently visualized nowadays, and other criteria have to be present for the diagnosis to be made.

We visualized the appendix in 25 (49 %) of the 51 patients in the non appendicitis group. We found that identification of an appendix measuring < 6mm in outer diameter under compression was a very accurate indication to exclude appendicitis, with a NPV of (96 %). Rettenbacher et al. [11] obtained a NPV of 100 % with this sign.

On the other hand, non visualization of the appendix was found to have a lower NPV for appendicitis (87%). Higher results were obtained in studies with high rates of visualization of normal appendix [12]. Thus, non visualization of the appendix can only be valid as an accurate sign to exclude appendicitis for sonographers who can usually identify a normal appendix.

The threshold outer diameter of 6 mm had both high NPV & high PPV of 96 % in this study. Rettenbacher et al. [11] obtained an outer appendiceal diameter of ≥ 6 mm in 32 % of patients without appendicitis. We found an appendiceal diameter of ≥ 6 mm in only 2 (8 %) of the 25 patients with visualized appendix in the non appendicitis group. A possible explanation could be the variability of the amount of compression used at the examination. We used maximal compression to standardize the measurements. Rioux [12] obtained comparable results to ours in this regard, when he found an appendiceal diameter of ≥ 6 mm in only 6 % of his patients without appendicitis.

Non compressibility of the appendix had identical PPV & NPV to the values of appendiceal diameter of ≥ 6 mm in this study. This is an expected finding since, if compressible, the appendiceal diameter will likely be < 6 mm under compression.

Fluid in, &/or absence of gas in the appendiceal lumen : Rettenbacher et al. [21] considered the absence of gas in the appendiceal lumen as a criterion for appendicitis. On the other hand, the clinical importance of appendicular air was considered debatable by Rao PM in 2000 [22]. Furthermore, gas in the appendicular lumen frequently resembles an appendicolith at US. Fluid in the appendicular lumen, on the other hand, is more easily detected at US. Thus we considered these two criteria together especially since their mechanism, usually obstruction, is the same. We found this sign in 33 (60 %) of 55 patients with visualized appendix in the appendicitis group, & in 3 (12 %) of the 25 patients with visualized appendix in the non appendicitis group.

Hyperaemia in the appendicular wall on color doppler was found to be a specific finding for acute appendicitis that was found in only 2 (8 %) of 25 patients with visualized appendix in the non appendicitis group. This is almost in accordance with previously published studies in which flow was never found in the normal appendiceal wall [23,24].

Inflammatory changes in the periappendiceal fat : we found this sign in 11 (22 %) of the 51 patients without appendicitis. Furthermore, we did not detect this sign in every patient of the appendicitis group. This is contradictory to the value of this sign at CT where inflammatory fat changes have been considered to be 100 % sensitive, but not a specific, sign of appendicitis. This is probably related to the fact that inflammatory fat changes are more easily detected at CT than at US.

Right lower quadrant adenopathy is a common reaction to ileal, cecal, or appendiceal inflammatory disease. This was encountered in both patients with and without appendicitis. we agree with previous conclusions [25,26,27] that the only definitive way to differentiate an appendiceal adenopathy from mesenteric adenitis is to identify either an inflamed or a normal appendix.

Cecal wall thickening didn't show sufficient predictive values to differentiate appendicitis from non appendicitis (PPV 64%, NPV 58%).

Peritoneal fluid was neither sensitive nor specific as a sign of appendicitis.

There were some limitations of our study : there was no reliable way to confirm that all patients without appendicitis would have had a normal appendix at histopathological analysis if surgery had been performed. Some of these patients might represent unrecognized cases of self limiting appendicitis especially since the concept of non resolving appendicitis is now supported by

evidence [28,29]. However, the same limitation apply to the results of other studies published in the same topic because not all patients suspected of having appendicitis undergo surgery.

Conclusion

A non compressible appendix with a threshold outer diameter of 6 mm under compression is the most indicative US finding for appendicitis with high NPV & PPV. A simple additional color doppler US examination may be helpful in the diagnosis of acute appendicitis when the appendix is equivocal in size at grey scale US.

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