Assessment of ultrasonography and computed tomography in the diagnostic strategy of suspected appendicitis

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"I prefer to exclude acute appendicitis in patients on CT rather at laparoscopy. Equally important - for surgeons who take emergency calls - CT has allowed us to sleep better and longer at night"

MOSHE SCHEIN IN 'ACUTE ABDOMINAL PAIN - DIAGNOSTIC IMPACT OF IMMEDIATE CT SCANNING', WORLD JOURNAL OF SURGERY 2007; 31:2358

Improving Diagnosis of Acute Appendicitis: Results of a Diagnostic Pathway With Standard Use of Ultrasonography Followed by Selective Use of CT

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Abstract

BACKGROUND Preoperative imaging has demonstrated to improve diagnostic accuracy in appendicitis. This prospective study assessed the accuracy of a diagnostic pathway in acute appendicitis using ultrasonography (US) and complementary contrast-enhanced MDCT (CT) in a general community teaching hospital.

STUDY DESIGN One hundred and fifty one patients with clinically suspected appendicitis followed the designed protocol: patients underwent surgery after a primary performed positive US (graded compression technique) or after complementary CT (contrast- enhanced MDCT) when US was negative or inconclusive. Patients with positive CT findings underwent surgery. When CT was negative for appendicitis, they were admitted for observation. The results of US and CT were correlated with surgical findings, histopathology, and follow-up.

RESULTS Positive US was confirmed at surgery in 71 of 79 patients and positive CT was confirmed in all 21 patients. All 39 patients with negative CT findings recovered without surgery. The negative appendicitis rate was 8% and the perforation rate was 9%. The sensitivity and specificity of US was 77% and 86%, respectively. The sensitivity and specificity of CT was both 100%. The sensitivity and specificity of the whole diagnostic pathway was 100% and 86 %, respectively.

CONCLUSIONS A diagnostic pathway using primary graded compression US and complementary MDCT in a general community teaching hospital yields a high diagnostic accuracy for acute appendicitis without adverse events due to delay in treatment. Although US is less accurate than CT, it can be used as a primary imaging modality, preventing the disadvantages of CT. For those patients with negative US and CT findings, observation is safe.

Introduction

The diagnosis of acute appendicitis is still an important and controversial problem. Based on clinical signs and symptoms, the normal appendix rate can still be as high as 15-40%.[1,2] Previous studies conflict whether the negative appendectomy rate can be decreased with the regular use of ultrasonography (US) and CT.[2-8] Although in most studies CT was found to have a better test performance than US, several authors have advocated the use of US as primary imaging modality, certainly given the negative exposure to radiation in this generally young patient population.[9-13]

Several prospective studies have compared the use of both US and CT in appendicitis in the same adult population. Yet, in none of these studies these imaging techniques were implemented in a diagnostic pathway and therefore the impact of imaging on the clinical handling could not be defined.[9,14] Considering the advantages and disadvantages of both US and CT, we designed a prospective study to evaluate a diagnostic pathway for appendicitis using both graded compression US and MDCT in all patients with clinically suspected appendicitis. The objective was to assess whether this diagnostic pathway could achieve a good diagnostic yield with limited adverse events due to delay in treatment, i.e. late perforations and complications due to delay in treatment.

Methods

The study was approved by the hospital's ethical committee for human studies. All patients between the ages of 18 and 80 years who had been presented to the emergency department with symptoms of acute appendicitis were eligible for this study. All patients were evaluated by a senior resident or a staff surgeon. Patients with typical signs of acute appendicitis (i.e., history, physical examinations findings and laboratory test results) who needed acute surgery (within 24 hr) and who had been admitted between 8 am and 10 pm, were included in the study. Patients who had been admitted outside office hours (between 10 pm and 8 am) were included the next morning if the condition of the patient allowed this. This was because of logistic considerations in the radiology department. Patients with atypical signs of acute appendicitis, who had been requested to return to the surgical outpatient department the next morning, were included if signs and symptoms of appendicitis had by then developed. Likewise, patients who had developed signs and symptoms of appendicitis during their clinical observation were also included.

Pregnant patients, patients with claustrophobia and patients with a previous appendectomy were not included. The radiologic procedures and logistics of the study were explained to

Table 1: Acute appendicitis: patient characteristics within diagnostic pathway

	N	Age Years (Range)	Sex (% Male)	BMI kg/m^2 (Range)	Clinical signs and symptoms (% positive)	
					Rebound tenderness	94%
US	151	29 (18-80)	44%	23.6 (15.8-40.7)	Fever (>37.5^{0}C)	59%
					Leucocytosis*(>11.5)	82%
					Rebound tenderness	93%
CT	60	30 (18-74)	39%	25.9 (17,1- 40.7)	Fever (>37.5^{0}C)	48%
					Leucocytosis*(>11.5)	68%

*Leucocytosis= elevated white bood cell count (>11.5 10^9 U/L)

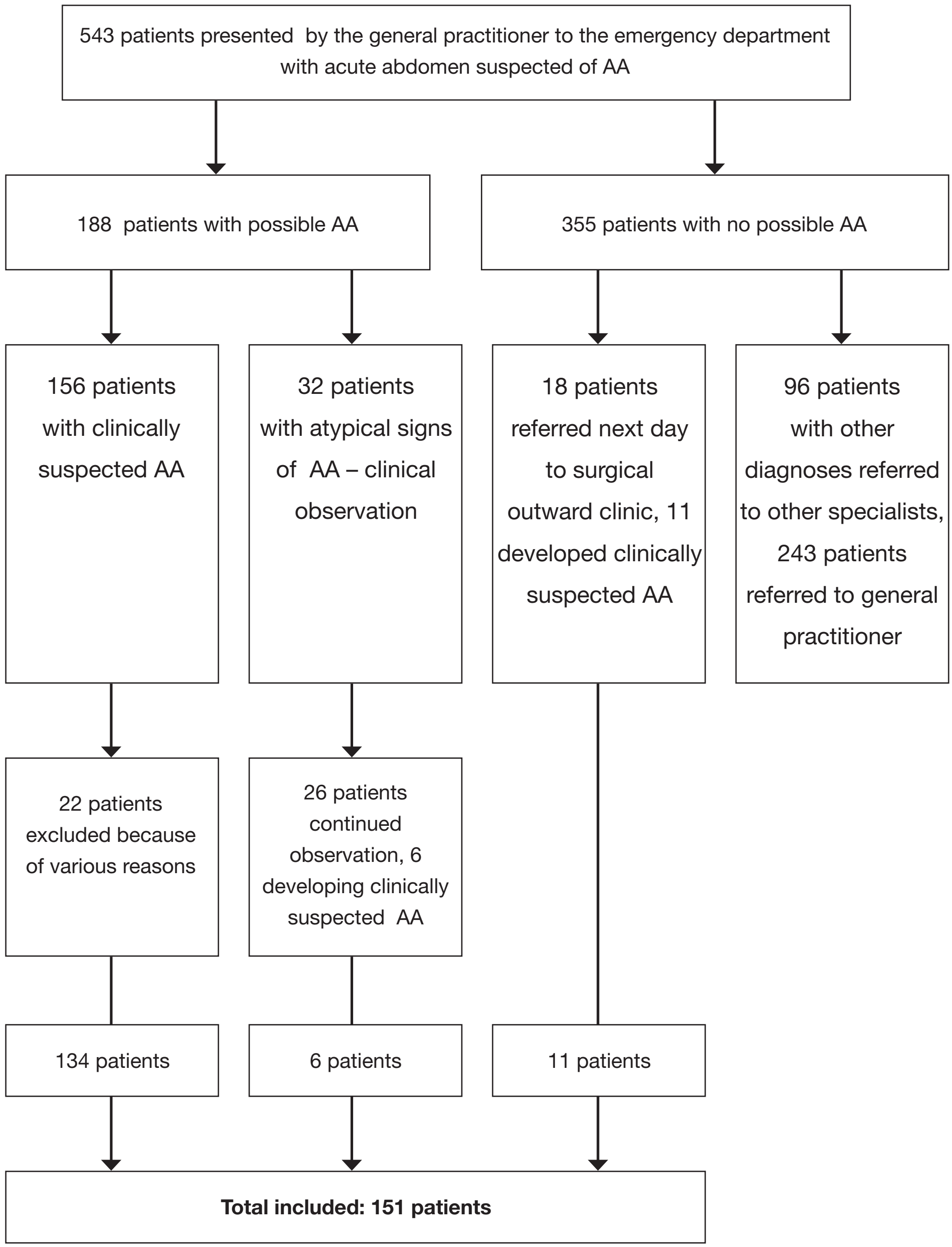
the patients, and informed consent was obtained from each patient. If other pathology was suspected, patients were referred to other specialists, as necessary.

Between February 2006 and December 2006, 543 patients had been presented to our emergency department with acute pain in the lower right abdomen. Figure 1 is a flow chart of these data. Twenty-two of the 156 patients with suspected acute appendicitis were excluded because of the following reasons: refusal to participate in the study (n = 8), admission after 10 pm needing acute surgery (n = 7), and other logistic reasons at the surgery and radiology departments (n = 7).

In total, 151 patients were included in the study. The patients' characteristics holding for age, sex, body mass index, and clinical parameters (rebound tenderness, fever and leucocytosis) are reported in Table 1.

The diagnosis of appendicitis or perforated appendicitis at surgery was based on macroscopic findings. A normal looking appendix at laparoscopy was left intact; a normal looking appendix at laparotomy by a split-muscle incision was excised. All excised appendixes were microscopically analyzed by histology using paraffin sections. The histological diagnosis of appendicitis was based on infiltration of the muscularis propria by neutrophil granulocytes. Other data collected included therapeutic procedure, rate of perforation, length of hospital stay, complications, and follow-up.

Figure 1: Acute appendicitis: flow chart of the study design



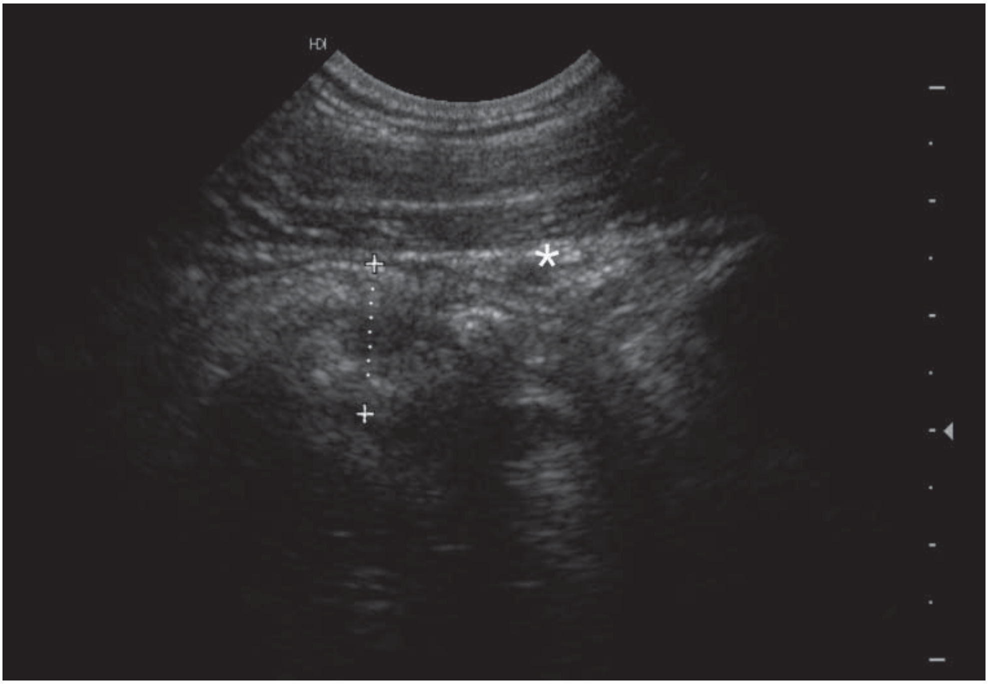


Figure 2: US of 28-year-old man shows echogenic incompressible inflamed fat (asterisk). The dotted line could be a possible enlarged retrocecal appendix, but an additional CT scan was needed to confirm the suspected diagnosis.

Diagnostic Pathway

The included patients underwent a standardized diagnostic pathway; primarily, US was performed. When US was positive for appendicitis, these patients underwent surgery (i.e. laparoscopy, laparotomy); if US was negative or uncertain, these patients underwent CT. If CT was positive or inconclusive for appendicitis, these patients underwent acute surgery; if CT was negative for appendicitis, these patients were admitted for observation. If during these hours of observation patients would develop worsening of clinical signs and symptoms (i.e., a clinical setback) the attending surgeon decided whether to perform an acute operation (i.e. laparoscopy, laparotomy) or not. If other relevant diagnoses than appendicitis were detected at CT and/or by US, the attending surgeon decided the best way to approach the alternative diagnosis.

Ultrasonography Examination

US (HDI 3000, ATL-Philips Medical Systems, Best, The Netherlands) was performed using the graded-compression technique[11], with 3,5- and 5-Mhz convex- and 7.5-Mhz linear-array

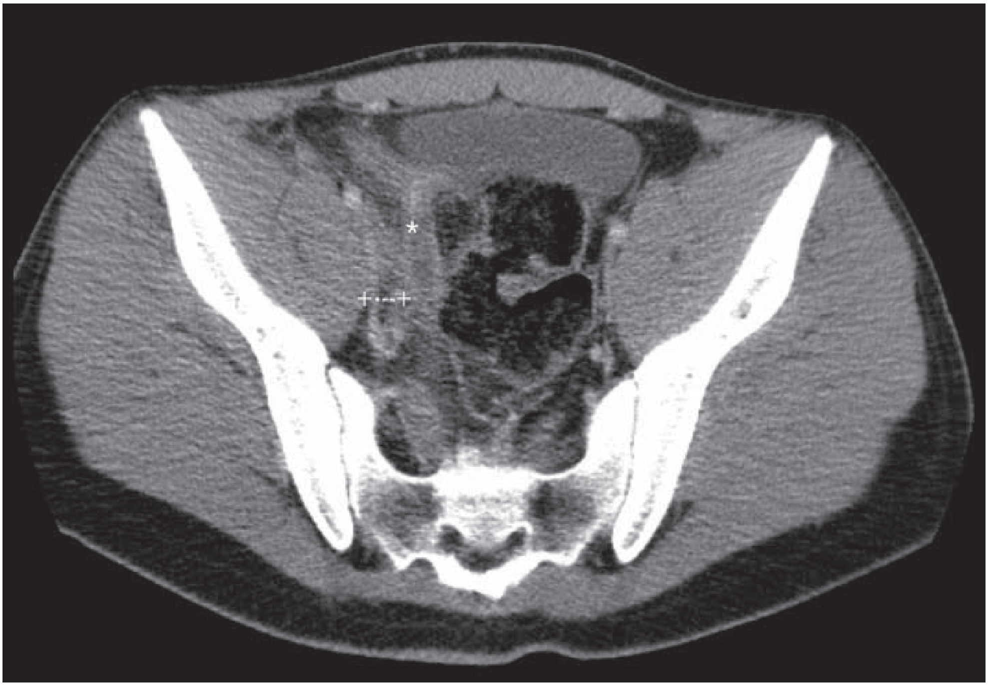


Figure 3. CT scan of the same patient shows classical appearance of appendicitis with periappendicular fat stranding (asterisk) and 13 mm enlarged appendix. Dotted line shows enlarged retrocecal appendix.

transducers, according to body size. Both US and CT assessments were based on criteria derived from reports in the literature.[1,15] Direct visualization of an incompressible appendix with an outer diameter of 6 mm or larger and echogenic incompressible periappendicular inflamed tissue with or without an appendicolith was the primary criterion to establish the diagnosis of acute appendicitis. A fluid filled appendix, hyperaemia within the appendiceal wall at color Doppler sonography, pericecal fluid, and abscess, were considered as possible positive criteria for acute appendicitis. US was considered negative for appendicitis only if a normal appendix could be entirely identified. If the appendix could not be visualized, the result of US was considered inconclusive and an additional CT was performed (see Fig. 2). After separately coding each finding, the radiologist was asked to propose an overall diagnosis for acute appendicitis (i.e., positive, negative or inconclusive).

Contrast-Enhanced MDCT Examination

All multidetector CT examinations were performed by using a sixteen-detector row CT machine (Philips Medical Systems, Best, The Netherlands). Scanning was performed with the following parameters: 1 second per rotation time, 1.5-mm collimation, and 32 mm/sec table

increment (pitch, 1.33). Images were acquired from the top of the L2 vertebral body to the pubic symphysis. All patients received intravenous contrast material (100-120mL iodixanol, Visipaque, 320 mg of iodine per milliliter), injected at a rate of 3-4 mL/sec, with a scanning delay of 70 seconds. Transverse sections were reconstructed with a 5 mm section thickness at 2.5 mm intervals. CT's were analyzed at a work station. A CT scan was read as positive for acute appendicitis if a distended appendix (≥ 6 mm in outer diameter) was visualized (see Fig. 3).
The presence of the following ancillary signs were coded as being positive for appendicitis: periappendiceal inflammatory changes, cecal wall thickening, appendicoliths, and abscess or phlegmon in the right iliac fossa. The presence of gas in the appendiceal lumen was considered as a possible negative criterion for appendicitis. After separately coding each finding, the radiologist was asked to propose an overall diagnosis for acute appendicitis (i.e., positive, negative or inconclusive).

Radiologist Responsible

Both US and CT examinations were performed by one of the 3 radiology staff members experienced in body imaging.

Reference Standard

The reference standard was surgery or conservative treatment. Imaging tests and therapy-hospitalization for surgery, observation before discharge from hospital - were performed within 6-12 hours of patient arrival the emergency department. Diagnostic performances of US and CT were compared with the reference standard for each patient.

Statistical Analysis

Statistical analysis was performed using the Statistical Package for the Social Sciences (SPSS) version 14.0. Sensitivity, specificity, positive predictive value, negative predictive value and accuracy of both US and CT as well as the complete diagnostic pathway were calculated. Ninety five per cent confidence intervals of the differences of sensitivity, specificity, positive predictive value, negative predictive value, and accuracy of the diagnostic strategies were constructed using the CIA program (confidence interval analysis, BMJ group).

Table 2: Acute appendicitis: mimicking diagnoses in US and CT studies

Diagnosis	No. of Pts	US	CT	Therapy
Cholecystitis	2	Diagnosed	Confirmed	Cholecystectomy
Rupture right pyelum (ureteral stone)	1	Free intra-abdominal fluid	Diagnosed	Referral to urologist
Right adnexal teratoma	1	Enlarged right adnex	Diagnosed	Referral to gynaecologist
Ovarian cyst	3	Adnexal pathology suspected	Diagnosed	Referral to gynaecologist
Malignant cecal tumor	1	Cecal mass	Diagnosed	Right hemicolectomy
Diverticulitis	2	Inflammatory changes sigmoid	Diagnosed	Conservative
Crohn’s disease	2	Inflammatory changes coecum	Diagnosed	Conservative
Total diagnoses	**12**			

Results

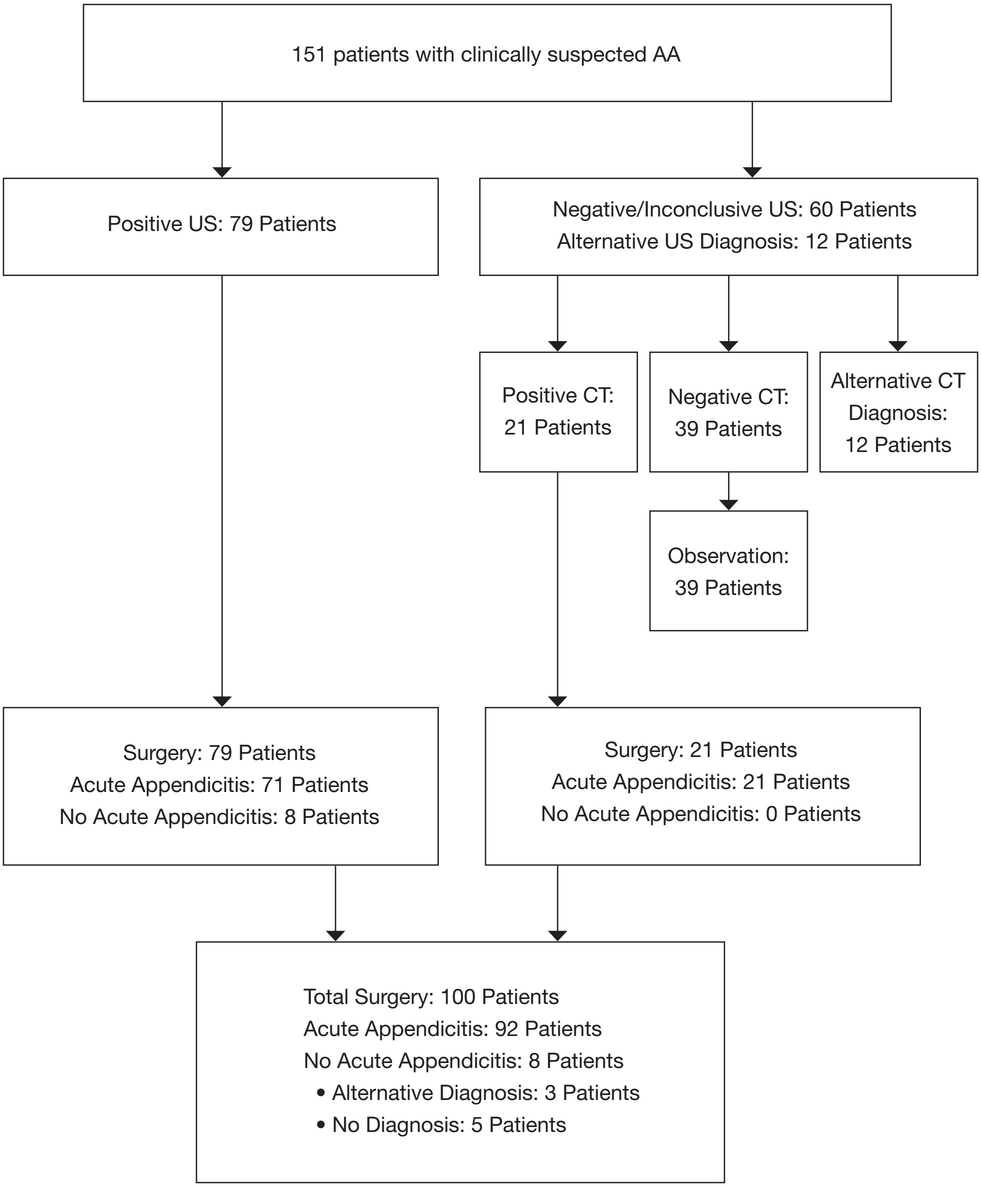
All 151 patients underwent primarily US. A flow chart of the results of US, CT and surgery in these 151 patients is shown in Fig. 4.

In 12 of the 151 patients (8%) , the surgeon was informed about other relevant diagnoses. These patients, US and CT findings of the alternative diagnoses and the clinical consequences are listed in Table 2.

US was positive for appendicitis in 79 patients (52%). All these patients underwent surgery. In 71 patients (90%) appendicitis was confirmed; in 5 patients a perforated appendicitis was found. In 8 patients (10%) a normal appendix was found and in 3 of these patients an alternative diagnosis was established. In 2 patients, a ruptured ovarian cyst was found and in one patient a corpus luteum was diagnosed. In 60 patients (40%) US was negative (31 patients) or inconclusive (29 patients) and these patients underwent additional CT scanning. In 21 patients (35%) CT showed signs of appendicitis, these patients underwent surgery. The diagnosis appendicitis was confirmed in all 21 patients (in 3 patients a perforated appendicitis was found). In 39 patients (65%) both US and CT were negative for appendicitis. These patients were admitted for clinical observation. This group recovered without surgery during clinical observation. No inconclusive CT assessments were reported.

The mean hospital stay was 2 days, ranging from 1 to 12 days. The mean follow up period was 4 months, ranging from 6 weeks to 12 months. Seven patients had complications. Two patients developed an intra-abdominal abscess after laparoscopic appendectomy and were treated successfully by percutaneous drainage. One patient with a wound infection after a

Figure 4: Acute appendicitis: results of a diagnostic pathway in 151 patients



split muscle appendectomy was treated by local wound drainage. Three patients recovered without surgery during clinical observation; yet were readmitted a few months later because of persistent right lower abdominal pain. One patient underwent a diagnostic laparoscopy and no abnormalities were found, but because of the persistent pain, an appendectomy was

Table 3: Acute appendicitis: overall performance values for US, CT and the diagnostic pathway

	US	CT	Diagnostic Pathway
Measurement	(n=151)	(n=60)	(n=151)
Sensitivity	77* (68-85)	100 (85-100)	100 (96-100)
Specificity	86 (76-93)	100 (91-100)	86 (76-93)
Pos Pred Value	90 (81-95)	100 (85-100)	92 (85-96)
Neg Pred Value	71 (60-80)	100 (91-100)	100 (93-100)
Accuracy	81 (74-86)	100 (94-100)	95 (90-97)

*Data are percentages. Numbers in parentheses are numbers of 95% confidence intervals

performed. The two other patients recovered without surgery. One patient was referred to a gynecologist. A diagnostic laparoscopy was performed and endometriosis was found.

In total, at surgery 92 (92%) of the 100 patients proved to have appendicitis and eight (8%) did not have appendicitis. In eight (9%) of the 92 patients, a perforated appendicitis was found. In three (3%) of these 100 patients, an alternative gynecologic diagnosis was made. In the other five (5%) patients, no explanation for the acute abdominal pain was found. Laparoscopic appendectomy was intended in 88 patients, but five patients eventually underwent open appendectomy for technical reasons. In 12 patients, primarily a split muscle incision was performed. In all 92 excised appendices, the microscopic evidence of acute appendicitis was seen at histology.

Statistical Data

The negative appendicitis rate in this study was 8% (8/100) and the perforation rate was 9% (8/92). The statistical data are shown in Table 3. There were no statistical differences with respect to gender.

Discussion

Implementing US and CT in a clinical pathway resulted in a high accuracy for diagnosing appendicitis. A low negative appendicitis rate (8%) can be achieved without adverse events due to delay in treatment because of false-negative imaging. Given the fact that three of the eight patients had a normal appendix at surgery, whereby an alternative diagnosis could be established, hence the actual negative appendicitis rate is 5%. This low negative appendicitis rate has also been reported in other studies using US and CT in the diagnosis of appendicitis.[3-5,8-13]

Although several prospective studies have compared the use of both US and CT in the diagnosis of appendicitis in the same adult patient group (showing CT having a better test performance than US)[9,14], a prospective validation of sequential use of graded compression US and CT in adult patients with signs of acute appendicitis has not been reported before. In a prospective study in pediatric patients and in two retrospective studies in adult patients US appeared to be valuable in the diagnosis of appendicitis and in inconclusive cases, additional CT could improve diagnostic accuracy.[13,16,17] These data are comparable with the present study results. US lacks radiation exposure, requires no patient preparation or contrast administration and can be a powerful imaging technique if the investigation is restricted to specialists.[8,11-13,18] In the current study, US was performed by 3 body imaging specialists. Sensitivity of US in our study was 77%, comparable to results from other studies.[8-15]

US was false-positive in 8 patients. In 7 of 8 sonograms with false-positive findings, the appendix was larger than 6.0 mm (varying from 8-10 mm), which is the accepted current limit of normal. Combined with experiencing severe pain in the right lower abdominal region during the US performance, the radiologist assessed US positive for appendicitis, which has also been described by other authors. [19,20,21]

When assessing patients suspected of having appendicitis, the inability to visualize the appendix with the use of US is classically considered a major weakness, because it represents a serious limitation to confidently excluding appendicitis.[1,15,22]

In our study, the appendix could not be visualized in 29 (19%) of the 151 patients, which corresponds to other previous studies.[20,21,23] In order to optimize pre-operative diagnostic accuracy, CT was performed in case of a negative or inconclusive US. In a previous study comparing the diagnostic accuracy of US and CT in appendicitis, the accuracy of both US and CT was 78%, but when combined almost as high as 100%.[14] If both US and CT were negative for appendicitis, it was regarded as safe not to operate the patient, but to admit the patient for clinical observation. In this study, both US and CT were negative for appendicitis in 39 patients. The specificity of CT in our study is 100%, a high score, also achieved in other studies.[9,10,13,24]

Some authors suggest that CT should be performed as the first imaging technique in all patients suspected of appendicitis.[4,5,24] In a recent meta-analysis of studies in patients with appendicitis, CT was found to have a better test performance than US, but authors make a case for US as the primary imaging modality for a select patient subgroup (young, female and slender patients) where radiation exposure is especially relevant.[9] It may be wise to pass over US in certain patient categories such as obese patients; trying US first could prevent a CT in 79 (57%) of the 139 patients. The trend in CT protocols nowadays is towards low-dose scanning, but radiation exposure is still considerable in CT.[9,10,25,26]

In our study, patients without signs of acute appendicitis using both US and CT, were clinically observed. None of these 39 patients developed signs or symptoms of acute appendicitis. These findings correspond to previous reports showing that active clinical observation can increase diagnostic accuracy without increasing morbidity and mortality from appendicitis.[27,28]

Our study has several limitations. First, we had no absolute confirmation of the absence of acute appendicitis in the non operated patients. Evidence suggests that spontaneous resolution of untreated, non-perforated appendicitis is common[29], which may underestimate the false-negative results and overestimate the false-positive results. This limitation is however also applied to other studies on this topic. Other evidence for unrecognized cases of self limiting appendicitis could be that a small percentage of 'normal' looking appendices removed during laparoscopy show acute appendicitis at histopathology.[30] However, the clinical consequence of this phenomenon is unclear and in correspondence with other studies we choose to leave a "normal" looking appendix in place.[31,32] Second, both US and CT were performed by experienced body imaging radiologists which might not reflect daily clinical practice in all hospitals, although other authors observed that the diagnostic performance for diagnosing appendicitis is not dependent on the expertise of a specific radiologist[15] Third, because of the ionizing radiation exposure, which is especially critical in children, our study group decided not to include pediatric patients.[33]

In conclusion, a diagnostic pathway following the standard use of US and complementary CT in patients with negative or inconclusive US results, yields a high diagnostic accuracy in the management of acute appendicitis without adverse events. Although US seems to be less accurate than CT, it can be used as a primary imaging modality for preventing the disadvantages of CT, especially patient preparation, contrast material administration, and radiation exposure. In patients with negative US and CT findings, conservative management is safe.

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