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

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"CT is able to diagnose an alternative condition, such as inflammatory bowel disease, infectious enteritis or colitis, intussusceptions, pancreatitis, hydronephrosis, pyelonephritis, Meckel's diverticulum, and abdominal neoplasms in up to 50% of pediatric and adult patients with clinically suspected appendicitis who undergo CT"

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Ultrasonography and CT of Acute Appendicitis: Influence of Gender on Diagnostic Accuracy and Ability to Identify Alternative Diagnoses

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Abstract

AIM To determine the influence of patient gender on the accuracy of ultrasonography (US) and CT in appendicitis and to assess the value of imaging in detecting alternative diagnoses. Patients and Methods: Data of a blinded prospective study in 199 patients with suspected appendicitis who underwent surgery after imaging were reevaluated with respect to patient gender-related differences in US and CT and the determination of alternative diagnoses.

RESULTS The negative appendectomy rate for 114 women and 85 men was 43% and 21%, respectively. Sensitivities of US for women and men were 70% and 87%, specificities were 78% and 67%. Sensitivities of CT for women and men were 72% and 82%, specificities were 86% and 67%. US and CT were able to provide alternative diagnoses in 12 of 33 women (36%) and 4 of 8 men (50%).

CONCLUSION Gender does have influence on the accuracy of US and CT in patients suspected of appendicitis. In women, use of US and CT are of limited value for detecting non-surgical alternative diagnoses.

Introduction

Diagnosing appendicitis continues to be a difficult task for physicians. Based on clinical signs and symptoms, the negative appendicitis rate can be 10%-20% in men, raising to 40%-50% in women.[1-3] To reduce the negative appendicitis rate, additional ultrasonography (US) and CT are increasingly used.[4,5] Studies have reported that CT has significant benefit in diagnosing women as it leads to a significant lowering of the negative appendicitis rate, thereby revealing the validity of alternative diagnoses that can mimic acute appendicitis.[6,7]

Only a few studies have examined the factor of patient gender-specific performance of US and CT in acute appendicitis.[5,8-10] We have previously reported our overall diagnostic accuracy of US and CT in acute appendicitis, yet in that study no differentiation was made between the factor of gender for women and men and no comparison was made between US and CT regarding alternative diagnoses made at surgery and findings by imaging.[11]

Therefore we carried out a reevaluation of these previously published data regarding the impact of gender on the negative appendicitis rate and the performance of US and CT in the diagnosis of acute appendicitis. In addition, the accuracy of using US and CT in diagnosing clinically relevant alternative disorders mimicking appendicitis in both men and women was assessed.

Materials and methods

Patient population

This study is a sequel to a previous study by Poortman et al.[11] and all patients who were included in the previous study were included in the present study. All patients with suspected acute appendicitis underwent US and CT before surgery. Need for surgery was based on clinical signs and symptoms and was decided by the attending surgeon.When admitted between 10 pm and 8 am, patients were clinically observed and underwent US and CT the next morning because of logistic considerations in the radiology department. Alternative diagnoses detected by US and on CT were listed. If important findings other than appendicitis were diagnosed on CT or US, an independent surgeon was informed. The independent surgeon decided whether the radiologic diagnosis was of consequence for the surgical strategy and whether the operation should be cancelled. One hundred and ninety-nine patients underwent surgery immediately or within 24 hours of observation after imaging. Between August 1998 and June 2000, 207 patients underwent both US and CT before surgery was performed. These patients consisted of 119 (58%) females and 88 (42%) males, their ages ranged from 3 to 89 years (mean 26 years).

Table 1. Acute appendicitis at surgery in 199 patients - 114 women and 85 men

	Women (n=114)	Men (n=85)	Total	p-value
Appendicitis	65 (57%)	67 (79%)	132 (66%)	0.0013
No appendicitis	49 (43%)	18 (21%)	67 (34%)	
Alternative diagnosis	33 (29%)	8 (9%)	41 (21%)	0.008
No diagnosis	16 (14%)	10 (12%)	26 (13%)	0.6

In eight patients (4%), the radiologist informed an independent surgeon about the radiologic findings before operation because of possible significant influence on the surgical management of the patient. In four of these eight patients, the operation was cancelled because both CT and US showed diverticulitis. In one patient, CT scan showed a teratoma of the right ovary, and in another patient an epidermoid cyst of the right ovary. These radiologic findings were confirmed at surgery. In one patient, CT and US showed acute cholecystitis which was confirmed by laparoscopy. In one patient, CT and US showed inflammation of the terminal ileum. A diagnostic laparoscopy validated these findings.

In total, 199 patients fully followed the designed protocol. This group (n=199) then made up our study group. The study protocol was approved by the hospital ethical committee for human studies, and written informed consent of the patient was obtained.

Ultrasonography examination

US (HDI 3000, ATL-Philips Medical Systems, Best, The Netherlands) was performed using the graded-compression technique,[12] with 3,5- and 5-Mhz convex- and 7.5-Mhz linear-array transducers, according to body size. Both US and CT assessments were based on criteria derived from reports in the literature.[4,9] 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 were the primary criteria to establish the diagnosis of acute appendicitis. A fluid filled appendix, pericecal fluid, and abscess were considered as possible positive criteria for acute appendicitis. The diagnostic criteria for negative findings on US were a compressible right lower quadrant without an enlarged appendix, right lower quadrant inflammation, phlegmon or abscess. After separately coding each finding, the radiologist was asked to propose an overall diagnosis for acute appendicitis (i.e., positive, negative or inconclusive).

Table 2. Acute appendicitis: alternative diagnoses made at surgery in 33 female patients

Diagnosis	No. Of Patients	US/CT	Therapy
Ovarian cyst	6	4 of 6 detected	Conservative
Corpus luteum	6	1 of 6 detected	Conservative
Gynecologic endometriosis or pelvic inflammatory disease	6	Not detected	Conservative
Morgagnian cyst	2	Not detected	Resection
Adnexal teratoma	1	Detected	Resection
Epidermoid cyst	1	Detected	Resection
Adhesions	2	Not detected	Adhesiolysis
Perforated diverticulitis	2	Detected	Sigmoid resection
Perforated Crohn's disease	1	Detected	Ileocecal resection
Perforated cecal tumor	1	Detected	Hemicolectomy
Infarcted omentum	1	Not detected	Resection
Cholecystitis	1	Detected	Cholecystectomy
Meckel's diverticulum	1	Not detected	Resection
Duodenal ulcer	1	Not detected	Conservative
Mesenteric adenitis	1	Not detected	Conservative
Total diagnoses	**33**		

CT scanning technique

CT examinations were performed with a single-detector helical CT scanner (Tomoscan AV, Philips Medical Systems, Best, The Netherlands) by means of a rapid thin-scanning technique. A single breath-hold helical scan from the top of the L2 vertebral body to the pubic symphysis was obtained using 5 mm beam collimation and 5-mm/sec table speed (pitch of 1120 kV,100-250mA). Images were reconstructed and photographed at 3-mm intervals using different soft-tissue window settings (width: 400H; level: 40 H). In patients younger than 10 years old, the tube current was 100mA and reconstruction filter 5 was used. In patients between 10 and 15 years old, the tube current was 150 mA and reconstruction filter 5 was used. In patients 15 years or older, the tube current was 250 mA and reconstruction filter 4 was used. No oral, rectal, or intravenous contrast material was administered. A CT scan was read as positive for acute appendicitis if a distended appendix (≥ 6 mm in outer diameter) was visualized. The presence of the following ancillary signs were coded as being positive for

Table 3: Acute appendicitis: alternative diagnoses made at surgery in 8 male patients

Diagnosis	No. of Patients	US/CT	Therapy
Infarcted omentum	2	Not detected	Resection
Mesenteric adenitis	1	Not detected	Conservative
Perforated Crohn's disease	1	Detected	Ileocecal resection
Perforated diverticulitis	1	Detected	Sigmoid resection
Perforated cecal tumor	2	Detected	Hemicolectomy
Meckel's diverticulum	1	Not detected	Resection
Total diagnosis	**8**		

appendicitis: periappendiceal inflammatory changes, cecal wall thickening, appendicoliths and abscess or phlegmon in the right iliac fossa. An appendix less than 6 mm in outer diameter was also diagnosed as normal. If an appendix was not visualized and ancillary signs were not present, the findings were interpreted as negative.

Radiologist Responsible

Both US and CT examinations were performed by a general radiology staff member or by a resident radiologist supervised by a staff who were alerted with the diagnosis "clinically possible appendicitis". US and CT were performed separately within 1 hr by two radiologists who were unaware of the findings on the other examination. The ratio of the contributions to this study of body imaging radiologists (n=2) to the other members of the radiology staff (n=10) was 2:12, which is similar to daily practice.

Reference Standard

The reference standard was surgery. Imaging tests and surgery were performed within 6-12 hours of patient arrival the emergency department. Surgery was performed without knowledge of the US and CT diagnosis. Diagnostic performances of US and CT were comparedwith the reference standard for each patient, especially with regard to patient gender and alternative diagnoses.

Statistical analysis

Statistical analysis was performed using the Statistical Package for the Social Sciences (SPSS) version 14.0. Ninety-five percent confidence intervals of the differences of sensitivity, specificity, positive predictive value, negative predictive value and accuracy of US and CT

Table 4. Correlation of US and surgery findings for diagnosis of acute appendicitis in 114 female and 85 male patients

US Female Patients			
Surgery	Positive	Negative	Total
Positive	46	19	65
Negative	11	38	49
Total	57	57	114

US Male Patients			
Surgery	Positive	Negative	Total
Positive	58	9	67
Negative	6	12	18
Total	64	21	85

Table 5. Correlation of CT and surgery findings for diagnosis of acute appendicitis in 114 female and 85 male patients

CT Female Patients			
Surgery	Positive	Negative	Total
Positive	47	18	65
Negative	7	42	49
Total	54	60	114

CT Male Patients			
Surgery	Positive	Negative	Total
Positive	53	14	67
Negative	6	12	18
Total	59	26	85

between male and female patients were calculated using the CIA program (confidence interval analysis, BMJ group). The chi-square test was performed to test differences in percentages between groups. Statistical significance was defined as $P<0.05$.

Results

Clinical results

In 199 patients, surgery was performed after imaging. Results for both women and men are listed in Table 1. The alternative diagnoses as found at surgery, including the findings of these diagnoses on US and CT, are listed in Table 2 for women and in Table 3 for men. In 12 of the 33 females (36%), use of US and CT led to these alternative diagnoses. In the other 16 patients (14%) without appendicitis, no explanation for the abdominal pain was determinable and the appendix was left intact. One of these patients was readmitted 4 months later and proved to have acute appendicitis at laparoscopy.

In 4 of the 8 males (50%), use of US and CT led to alternative diagnoses confirmed at surgery. In the other 10 patients without appendicitis no diagnostic explanation for the abdominal pain was made and in 4 patients the appendix was excised because an open procedure was performed. Upon microscopic examination, these removed appendices proved not inflamed.

Table 6. Statistical data of US and CT in acute appendicitis

US

	Sensitivity	Specificity	PPV*	NPV*	Accuracy
Female	71%	78%	81%	67%	74%
Male	87%	67%	91%	57%	82%
Difference	-16%	11%	-10%	10%	-8%
95% CI difference	-29% to 2%	-11% to 36%	-23% to 3%	-13% to 33%	-20% to 3%

CT

	Sensitivity	Specificity	PPV*	NPV*	Accuracy
Female	72%	86%	87%	70%	78%
Male	79%	67%	90%	46%	77%
Difference	-7%	19%	-3%	24%	1%
95% CI difference	-21% to 8%	-2% to 43%	-16% to 9%	2% to 44%	-10% to 14%

*PPV = Positive Predictive Value *NPV = Negative Predictive Value

US and CT results

The US results for both the women and the men who underwent surgery are listed in Table 4 and the CT results are listed in Table 5.

Statistical data

The negative appendicitis rates found in this study are the scores of 43% for women and 21% for men (p=0.0013).

Statistical data are listed in Table 6. Apart from the difference in negative predictive value for CT between women and men, the differences are not statistically significant.

Discussion

In the present study, which is a further analysis of a blinded prospective study on the value of US and CT in acute appendicitis,[11] we can determine differences in the accuracy of using US and CT holding for gender. The difference in the negative predictive value of CT is determined to be statistically significant in favor of accurately diagnosing women, the other differences are not statistically significant. We can conclude that applying US and CT has been able to

provide an alternative diagnosis in half of the men and in one-third of the women involved in the study.

Based on clinical signs and symptoms, the negative appendicitis rate in this study was 43% for women and 21% for men, which corresponds to other studies.[1-4] Reason for this relatively high negative appendicitis rate can be explained by the fact that both typical and atypical patients were included. Especially in women experiencing acute lower abdominal pain, the symptoms may be caused by acute gynecologic etiologies mimicking acute appendicitis. In our study, the most important gynecologic and gastro-intestinal diagnosis requiring surgery were detectable on US and CT. Yet, in 15 of the 20 patients with self-limiting alternative diagnoses, both US and CT were unable to identify these diagnoses. The majority of these diagnoses were gynecologic. The limited performance of CT in these disorders is described in other studies,[13,14] but the fact that CT scanning was performed without oral, rectal or intravenous contrast may also have attributed to failing accuracy in detecting these alternative diagnoses.[15] In acute gynecologic etiologies in early conditions, endovaginal pelvic ultrasound is probably more valuable.[12,16] In men, diagnoses with potential clinical management consequences such as diverticulitis, Crohn's disease and colonic malignancies were detected by CT as well as US, but self-limiting disorders such as mesenteric adenitis and infarcted omentum were not identified on US and CT. Several authors suggest that women suspected of acute appendicitis benefit more from a diagnostic laparoscopy than US and CT.[2,3,17] In our present study, use of US and CT led to identification of alternative diagnoses requiring surgery in both women and men, but still failed to detect self-limiting or with use of medical therapy treatable diagnoses. The surplus value of diagnostic laparoscopy in our study is the fact that it could provide an explanation and possible management for the lower abdominal pain in non-surgical, mostly gynaecologic, diagnoses.

Because of the high negative appendicitis rate in women, additional imaging is considered to be beneficial.[4-7] However, gender analysis using US and CT has not been widely reported. Balthazar et al. compared the accuracy of CT and US in acute appendicitis and except for a decrease of sensitivity of US in women (76% vs. 61%), CT and US yielded a similar accuracy.[9] Raman et al. evaluated the relation between patient gender and its impact on CT in diagnosing acute appendicitis and except for a slight decrease in sensitivity (100% vs. 94%) in thin women, no differences were detected.[8] The results in our study show notable differences in the sensitivity, specificity, positive and negative predictive value of US and CT between men and women. However, except for the difference in the negative predictive value of CT (in favor of women), no statistical significant influence of gender on diagnostic accuracy was proven. Reason for this is the fact that in this study, the data had been collected

prospectively, but the gender analysis was done retrospectively. This may have led to a type 2 error because of a too small sample size. In our study, we did observe a trend and further prospective studies with special interest in the influence of gender on diagnostic accuracy of US and CT are needed. A reason for the differences in sensitivity and specificity may be the patients' body habitus. In obese patients, US may be more difficult to interpret than CT, whereas CT maybe more difficult to interpret in thin patients.[8] Because in the collection of the data the factor of body habitus was disregarded, it cannot be concluded from this study that such a patient related factor was of influence.

This study has limitations. Foremost, the equipment used in the primary study was a single-detector helical CT. We realize that almost all facilities now have MDCT's possessing greater sensitivity. Secondly, we also realize that oral and intravenous contrast material application, thin-collimation and, eventually, multiplanar reconstructions might improve the quality of interpretation. The aim of this study, however, was to determine the influence of gender on the accuracy of US and CT in an average teaching hospital by performing a reassessment within the original setup of the primary study.

In conclusion, gender does have influence on the accuracy of US and CT in patients suspected of acute appendicitis, although no statistical significance could be established. In cases of an alternative diagnosis in men, surgery is mostly needed, whereas gynecologic diagnoses causing acute lower abdominal pain in women rarely necessitate surgery. US and CT can be said to be of limited value in diagnosing alternative disorders whereby surgery is not needed.

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