



Improving the false-negative rate of CT in acute appendicitis—Reassessment of CT images by body imaging radiologists: A blinded prospective study

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ABSTRACT

Purpose: To compare the accuracy of computed tomography (CT) analyzed by individual radiology staff members and body imaging radiologists in a non-academic teaching hospital for the diagnosis of acute appendicitis.

Patients and methods: In a prospective study 199 patients with suspected acute appendicitis were examined with unenhanced CT. CT images were pre-operatively analyzed by one of the 12 members of the radiology staff. In a later stage two body imaging radiologist reassessed all CT images without knowledge of the surgical findings and without knowledge of the primary CT diagnosis. The results, independently reported, were correlated with surgical and histopathologic findings.

Results: In 132 patients (66%) acute appendicitis was found at surgery, in 67 patients (34%) a normal appendix was found. The sensitivity of the primary CT analysis and of the reassessment was 76% and 88%, respectively; the specificity was 84% and 87%; the positive predictive value was 90% and 93%; the negative predictive value was 64% and 78%; and the accuracy was 78% and 87%.

Conclusion: Reassessment of CT images for acute appendicitis by body imaging radiologists results in a significant improvement of sensitivity, negative predictive value and accuracy. To prevent false-negative interpretation of CT images in acute appendicitis the expertise of the attending radiologist should be considered.

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1. Introduction

In patients with suspected acute appendicitis computed tomography (CT) has proven to be an accurate imaging technique. CT has reported sensitivities of 70–100% and specificities of 91–100% [1]. However, the majority of these studies are performed in centres

with dedicated expertise and in most of the cases expert interpretation of the images is provided.

Because most patients with acute appendicitis present at any time of the day in general community hospitals interpretation of CT scans is in the hands of in house staff. These health care professionals might have limited expertise in diagnosing appendicitis.

Few studies describe the influence of expertise of radiologists on the diagnostic accuracy of CT in acute appendicitis. Some authors describe no disagreement between resident and attending radiologists in the interpretation of CT scan in patients suspected of having appendicitis [2–4], whereas others show interobserver variability in the evaluation of the CT images between radiologists with different levels of experience [5,6].

Before the implementation of CT as the standard pre-operative imaging technique in our teaching hospital we decided to compare the results of the interpretation of CT images by the general radiology staff, published in a previous study [7], by reassessing all the CT images by two body imaging radiologists. Results of this

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reassessment of CT images in acute appendicitis are presented in this study.

2. Patients and methods

2.1. Subjects

Because this study is a sequel to a previous study by Poortman et al. [7] we refer for the materials and methods used in this study to the mentioned previous study. All patients who were included in the previous study were included in the present study. In summary, all patients with suspected acute appendicitis underwent CT before surgery. When admitted between 10 pm and 8 am patients were clinically observed and underwent CT the next morning because of logistic considerations in the radiology department. One hundred and ninety-nine patients underwent surgery immediately or within 24 h of observation after imaging.

2.2. 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/s table speed (pitch of 1120 kV, 100–250 mA). Images were reconstructed and photographed at 3-mm intervals using different soft-tissue window settings (width: 400H; level: 40H). In patients younger than 10 years old, the tube current was 100 mA 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 IV 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 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. An appendix less than 6 mm in outer diameter was also diagnosed as normal. If an appendix was not visualized and ancillary signs were or were not present, the findings were interpreted as negative.

2.3. Image analysis

CT scans were analyzed pre-operatively at a workstation by general radiology staff members who were alerted with the diagnosis “clinically possible appendicitis”. The CT examination was performed within 1 h by a general radiology staff member or by a resident radiologist supervised by a staff member. 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. The CT diagnosis was pre-operatively established and registered.

The reassessment of each individual CT image was performed by one of the two body imaging radiologists at a later date (after the study was finished). Both body imaging radiologists reassessed approximately the same amount of CT scans and no shared consultation took place. They were also only alerted to “clinically possible appendicitis” and unaware of the diagnosis made at surgery. The primary CT diagnosis nor the primary reader were known by the two body imaging radiologists. The results were correlated with surgical and histopathologic findings.

2.4. 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 the primary assessment and the reassessment were calculated. Ninety-five per cent confidence intervals of the differences of sensitivity, specificity and accuracy were constructed using the CIA program (confidence interval analysis, BMJ group).

The study protocol was approved by the hospital's ethical committee for human studies.

3. Results

3.1. Surgical findings

At surgery 132 of the 199 patients (66%) proved to have acute appendicitis and 67 patients (34%) did not have acute appendicitis. In 41 of these 199 patients (21%) another relevant diagnosis was made. In most cases this diagnosis was gynecological. These diagnoses are listed in Table 1. In the other 26 patients without appendicitis (13%), no diagnosis was made and the appendix was left intact. One of these patients was re-admitted 4 months later and proved to have acute appendicitis at laparoscopy.

3.2. CT findings

The results of the primary CT findings and the CT findings after reassessment of all the CT images by two body imaging radiologists are listed in Table 2.

3.3. Statistical data

Statistical data are shown in Table 3. For sensitivity, negative predictive value and accuracy the differences are statistically significant in favour of the reassessment. The differences for specificity and positive predictive value are not statistically significant.

3.4. Histopathologic findings

During laparoscopy healthy-looking appendices were not removed. In two of these cases, the patients were re-admitted

Table 1
Acute appendicitis: alternative diagnoses made at surgery in 41 patients.

Diagnosis	No. of patients	Therapy
Gynecologic		
Ovarian cyst	6	Conservative
Corpus luteum	6	Conservative
Adnexal teratoma	1	Resection
Epidermoid cyst	1	Resection
Cyst of Morgagni–torsion	2	Resection
Endometriosis/PID	6	Conservative
Total gynecologic diagnoses	22	
Gastro-intestinal diagnoses		
Diverticulitis	3	Sigmoid resection
Crohn's disease	2	Ileocolic resection
Infarcted omentum	3	Resection
Cecal tumor (malignancy)	3	Hemicolectomy
Adhesions	2	Adhesiolysis
Cholecystitis	1	Cholecystectomy
Meckel's diverticulum	2	Diverticulectomy
Duodenal ulcer	1	Conservative
Mesenteric adenitis	2	Conservative
Total gastro-intestinal diagnoses	19	
Total	41	

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