MRI in suspected appendicitis
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Citation for published version (APA):

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CHAPTER 6

Accuracy of magnetic resonance imaging compared with a protocol of ultrasound imaging and selective use of computed tomography for discriminating simple from perforated appendicitis

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Br J Surg; Epub ahead of print
ABSTRACT

Background
Discrimination between simple and perforated appendicitis in patients with suspected appendicitis helps to determine therapy, timing of surgery, and the risk of complications. The aim of this study was to estimate the accuracy of Magnetic Resonance Imaging (MRI) in distinguishing between simple and perforated appendicitis, and to compare it against ultrasound with conditional Computed Tomography (CT).

Methods
Patients with clinically suspected appendicitis were prospectively identified at the emergency department of six hospitals. Consenting patients underwent MRI, but were managed based on ultrasound and use of conditional CT. Radiologists who evaluated MRI were blinded for results of ultrasound and CT and vice versa. Presence of perforated appendicitis was prospectively recorded after each evaluation. The final diagnosis was assigned by an expert panel based on perioperative data, histopathology and clinical follow up after 3 months.

Results
MRI was performed in 223 of 230 included patients. Acute appendicitis was the final diagnosis in 118 of 230 patients; 87 simple and 31 perforated appendicitis. MRI correctly identified 17 of 30 patients with perforated appendicitis (sensitivity 0.57; 95% c.i. 0.39-0.73), ultrasound with conditional CT identified 15 of 31 (sensitivity of 0.48; 95% c.i. 0.32-0.65, \(p=0.517\)).

All missed diagnoses of perforated appendicitis were identified as simple acute appendicitis in both imaging protocols.

Conclusion
MRI is comparable to ultrasound with conditional use of CT in identifying perforated appendicitis. Both strategies miss many patients with perforated appendicitis, incorrectly classifying them as simple appendicitis cases. Triage of appendicitis based on imaging for conservative treatment is inaccurate and may be unsafe.
INTRODUCTION
Appendectomy for acute appendicitis has been recently questioned as being the only correct treatment for appendicitis. Antibiotic treatment has been shown to be effective in the management of selected patients with acute non-perforated (simple) appendicitis in randomized controlled trials.1–5 Also, there is some evidence for the spontaneous resolution of untreated, non-perforated appendicitis.6 The complication rates for conservative management increase with perforation, which is associated with higher failure rates in patients with perforation. In addition, previous studies have revealed a 3.5 to 10-fold increase in mortality rate following perforation.5,7 An accurate preoperative diagnosis of perforation is therefore clinically relevant in determining treatment, timing of surgery, and in evaluating the risk of complications.

Diagnostic imaging with ultrasound (US) or computed tomography (CT) has been proven to accurately detect acute appendicitis.8 However, these imaging modalities do not seem to be as effective in differentiating simple appendicitis cases from perforated appendicitis cases. For ultrasound, the reported sensitivities vary from 29 to 84 per cent.9,10 More recent studies that evaluated the accuracy of CT in detecting perforated appendicitis reported sensitivities between 28 and 62 per cent with specificities between 81 and 91 per cent.11–13 In a recent randomized controlled trial the investigators selected patients with simple acute appendicitis by systematic CT-scan assessment prior to randomisation between conservative or operative treatment.1 Despite the use of CT complicated appendicitis with peritonitis was found at surgery in 18 per cent of patients in the appendectomy group.

Magnetic resonance imaging (MRI) is a promising modality in the evaluation of patients with suspected acute appendicitis due to its high diagnostic accuracy, lack of ionizing radiation and intravenous contrast medium.14,15 Newer MRI techniques such as diffusion-weighted imaging may further increase its accuracy.16,17 Because the use of MRI for the evaluation of acute appendicitis is relatively new, data on accuracy for perforated versus simple appendicitis are not yet available in the literature.

We designed a study to estimate the accuracy of MRI for diagnosing perforated appendicitis in patients with suspected acute appendicitis. First, we aimed to compare the accuracy of MRI to the currently used imaging strategy for evaluation of suspected appendicitis by the initial use of US followed by CT in case of a negative or inconclusive US results.18,19 Our secondary aim was to identify MRI features associated with perforated appendicitis.

METHODS
Patient selection
For this prospective multicenter diagnostic accuracy study we included adult patients (≥18 years) with clinically suspected acute appendicitis in the emergency department (ED) of six hospitals.20 All participating patients gave written informed consent; the hospital’s Medical Ethical Committee approved our study protocol prior to study initiation.20 Treating physicians in the ED identified and recruited patients with clinically suspected appendicitis based on medical history, physical and laboratory examination prior to imaging.
We excluded pregnant women, patients with any contraindication for MRI and critically ill patients that needed intensive vital organ function monitoring for life-support. Consenting patients underwent an MRI within two hours for research purposes, but were managed based on US and CT findings, according to Dutch guidelines (US with conditional CT). Initially a staff radiologist or radiological resident performed the US, evaluating the complete abdomen. A curved 3.5 – 5.0 MHz array and a linear 10 MHz array were used (‘Aplio XL’ Toshiba Medical Systems, Tokyo, Japan; ‘HDI 5000’ and ‘IU 22’, Philips Medical Systems, Best, The Netherlands; ‘Acuson’ and the ‘Antaris’ Siemens Medical Systems, Forchheim, Germany) In case of negative or inconclusive US results, CT was subsequently performed. All CT scans were performed using a multi-detector row 4, 16 or 64 slice CT scanner (4-slice SOMATOM Volume Zoom, 16-slice SOMATOM sensation, Siemens Medical Systems, Forchheim, Germany; 16-slice MX 8000, 64-slice Brilliance, Philips Medical Systems, Best, The Netherlands; 64-slice Aquilion, Toshiba Medical Systems, Tokyo, Japan) and intravenous contrast medium and were read by a staff radiologist or supervised radiological resident. Any diagnosis of perforated appendicitis at US and CT was recorded prospectively during this study (Appendix A).

MRI protocol

Included patients underwent MRI at a 1.5T scanner (MAGNETOM Avanto 1.5T MRI, Siemens Medical Systems, Forchheim, Germany or Intera 1.5T MRI Philips Medical Systems, Best, The Netherlands) within two hours of admission to the ED. The MRI examination comprised breath hold axial and coronal T2 weighted sequences (HASTE: TR 1500ms, TE 90ms, flip angle 170, slice thickness 6 mm, FOV 400 mm, 256x256 matrix; SPAIR HASTE: TR 1400ms, TE 93ms, flip angle 160, slice thickness 6 mm, FOV 400 mm, 256x256 matrix) and free breathing axial and coronal diffusion weighted sequences (diffusion-weighted imaging: TR 3900ms, TE 75ms, slice thickness 6mm, FOV 400mm, 192x192 matrix B-values 50 - 400 – 800s/mm²), 192x192 matrix). No intravenous or oral contrast medium was administered.

Image interpretation

Two experienced radiologists (>500 MRI readings of the abdomen) read the MRI in a research setting on a picture archiving and communication system working station. They received clinical information on each included patient but were blinded from the results of US, CT and outcome. The radiologists evaluated the MRIs separately, differences were resolved by consensus. The presence of perforated appendicitis, and presence of the following imaging findings were recorded; complete visualization of the appendix, appendix diameter, peri-appendiceal fat infiltration, peri-appendiceal fluid, absence of intraluminal air, presence of an appendicolith, destruction of the appendiceal wall, presence of an abscess and extra-luminal free air. Findings of diffusion-weighted imaging: restricted diffusion of appendiceal wall, lumen and focal fluid collections. The radiologists recorded imaging findings and the final judgement on the presence of appendicitis and appendiceal perforation in a structured case record form (Appendix A). The diagnosis on appendiceal perforation was left at the discretion of the reader who evaluated the images.
Reference standard

All cases were assigned to one of two expert panels, each consisting of two surgeons and one radiologist. The panel assigned a final diagnosis based on peroperative observation, histopathological findings and three months follow up. If patients had not returned to the hospital within this period their general practitioner was contacted for information. The diagnosis was classified as; ‘no appendicitis’ (any other diagnosis), ‘simple appendicitis’ or ‘perforated appendicitis’. Criteria for perforated appendicitis were peri-operative observation of a perforation in the appendix, pus in the abdomen or perforation at histopathological examination. Conflicting findings at peri-operative observation, histopathological examination or clinical findings were resolved during consensus meetings of the two expert panels.

Data analysis

The diagnostic accuracy for perforated appendicitis was evaluated for MRI and for US with conditional CT. Estimates of sensitivity, specificity and predictive values were calculated with corresponding 95% confidence intervals, by comparing the imaging results to the final diagnosis assigned by the expert panel. For these calculations only imaging results positive for perforated or simple appendicitis were used. We considered cases of perforated appendicitis in which imaging identified ‘perforated appendicitis’ as true positives, and perforated appendicitis cases identified as ‘simple appendicitis’ as false negatives. We considered cases of simple or no appendicitis as false positives if imaging identified ‘perforated appendicitis’, and true negative if imaging identified them as ‘simple appendicitis’. Differences in sensitivity, specificity and predictive values were tested for statistical significance with the chi-square test statistic. P-values below 0.05 were considered to indicate statistical significance. With an MRI sensitivity in detecting perforated appendicitis of around 60%, and about one in seven patients with suspected appendicitis having a final diagnosis of perforated appendicitis, the inclusion of 230 patients produces a 95% confidence intervals that extends 15% from the estimated sensitivity.

The presence of complete visualization of the appendix, enlarged appendix diameter, peri-appendiceal fat infiltration, peri-appendiceal fluid, absence of intraluminal air, presence of an appendicolith, destruction of the appendiceal wall, presence of an abscess, extraluminal free air, restricted diffusion of appendiceal wall, lumen and focal fluid collections was compared between patients with perforated and simple appendicitis as final diagnosis using the chi-square test statistic. Estimates of positive and negative predictive value for perforated appendicitis were calculated per MRI feature, with The initial US identified 17 patients with perforated appendicitis. In this group the final diagnosis was perforated appendicitis in ten patients (10 true positives), simple appendicitis in six, and one patient was diagnosed with an adenocarcinoma of the caecum (7 false positives; 11 patients with perforated appendicitis were not identified by US; the sensitivity for perforated appendicitis of US alone was 48 per cent (10/21; 95% c.i. 28 to 68 per cent). After inconclusive or negative US findings for acute appendicitis a CT was performed in 115 patients. Another five patients were correctly identified with perforated appendicitis (5 true positives) by this investigation. The CT did not generate any additional false positives. corresponding 95% confidence intervals. This was also calculated
for the combination of any two MRI features. The association between each imaging feature and a final diagnosis of perforated acute appendicitis was expressed as a diagnostic odds ratio with corresponding 95% confidence interval. All statistical analyses were performed with SPSS software (SPSS Inc. Chicago, Illinois, USA, version 18.0).

RESULTS

Between March 2010 and September 2010, a total of 230 patients with clinically suspected appendicitis were included, their median age was 35 years (interquartile range 24 to 49), 92 were male. After completion of the imaging protocol 128 patients underwent surgery within a few hours of diagnostic imaging, histopathology was available in 123 of patients. Two patients with perforated appendicitis were treated non-operatively with percutaneous drainage. The expert panel assigned acute appendicitis as the final diagnosis in 118 patients, of which 31 had a perforated appendicitis (perforation rate 26 per cent).

Diagnostic accuracy of ultrasound imaging with conditional computed tomography for appendiceal perforation

The imaging protocol was violated in eight patients: one patient, in whom direct CT was performed without initial US, and seven patients in whom no CT was performed after a negative or inconclusive US. The flowchart in Figure 1a summarizes findings of conditional CT.

![Figure 1a. Flowchart imaging results US with conditional CT](image-url)
The initial US identified 17 patients with perforated appendicitis. In this group, the final diagnosis was perforated appendicitis in ten patients (10 true positives), simple appendicitis in six, and one patient was diagnosed with adenocarcinoma of the caecum (7 false positives; 11 patients with perforated appendicitis were not identified by US; the sensitivity for perforated appendicitis of US alone was 48% (10/21; 95% c.i. 28 to 68% per cent). After inconclusive or negative US findings for acute appendicitis, a CT was performed in 115 patients. Another five patients were correctly identified with perforated appendicitis (5 true positives) by this investigation. The CT did not generate any additional false positives.

In 208 patients appendiceal perforation was excluded by US, with conditional CT; 103 of these patients were diagnosed with simple appendicitis. In this group, 16 were diagnosed with perforated appendicitis by the expert panel (16 false negatives, 87 true negatives). In the other 105 patients, simple appendicitis was excluded, three had simple appendicitis and none of these patients had perforated appendicitis as final diagnosis (Table 1).

In summary, US with conditional CT discriminated ‘perforated appendicitis’ from ‘simple appendicitis’ or ‘no appendicitis’ with a positive predictive value of 68% per cent (15/22; 95% c.i. 47 to 84% per cent) and a negative predictive value of 84% per cent (87/103; 95% c.i. 76 to 90 per cent). The sensitivity of US with conditional CT in detecting perforation of the appendix was estimated at 48% per cent (15/31; 95% c.i.: 32 to 65 per cent) (Table 2).

Diagnostic accuracy of magnetic resonance imaging for appendiceal perforation

In 7 of the 230 included patients MRI could not be performed due to claustrophobia or unexpected technical failure. The final diagnoses in these 7 patients were: perforated appendicitis (1), acute diverticulitis (1), acute cholecystitis (1), benign adnex cyst (2), simple urinary tract infection (1) and non-specific abdominal pain (1).

The flowchart in Figure 1b summarizes findings of MRI. Radiologists classified 30 patients as perforated acute appendicitis cases based on MRI; this was confirmed at surgery in 17 patients (17 true positives). Simple appendicitis was the final diagnosis in twelve of these 30 patients, along with non-specific abdominal pain (1 patient).
Table 2. Accuracy of magnetic resonance imaging and ultrasonography with conditional computed tomography for perforated appendicitis

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>Sensitivity (%)</th>
<th>Specificity (%)</th>
<th>PPV (%)</th>
<th>NPV (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ultrasound imaging with conditional CT</td>
<td>125</td>
<td>48 (32-65)</td>
<td>93 (85-96)</td>
<td>68 (47-84)</td>
<td>84 (76-90)</td>
</tr>
<tr>
<td>Magnetic resonance imaging</td>
<td>120</td>
<td>57 (39-73)</td>
<td>86 (77-91)</td>
<td>57 (39-73)</td>
<td>86 (77-91)</td>
</tr>
<tr>
<td>P*</td>
<td></td>
<td>0.517</td>
<td>0.127</td>
<td>0.399</td>
<td>0.833</td>
</tr>
</tbody>
</table>

Values in parentheses are 95 per cent confidence intervals; proportions used to calculate diagnostic indices are also shown. Only imaging results positive for perforated or simple appendicitis were used for these calculations. Conditional computed tomography (CT), all patients underwent initial ultrasonography, then CT if the ultrasound results were negative or inconclusive. PPV, positive predictive value; NPV, negative predictive value. * χ² test.

Figure 1b. Flowchart imaging results MRI

in one patient laparotomy showed an infiltrate with involvement of the appendix and adnex in the right lower abdomen due to endometriosis (13 false positives). Radiologists classified 90 patients as simple acute appendicitis with MRI; 13 of these 90 patients had a perforated appendicitis at surgery (13 false negatives, 77 true negatives). The remaining 103 patients were not diagnosed with appendicitis; none of them had perforated appendicitis as final diagnosis.

MRI discriminated perforated appendicitis from ‘simple appendicitis’ or ‘no appendicitis’ with a positive predictive value of 57 per cent (17/30; 95% CI 39 to 73 per cent) and a negative predictive value of 86 per cent (77/90; 95% CI 77 to 91 per cent). MRI sensitivity in detecting perforated appendicitis was 57 per cent (17/30; 95%CI: 39 to 73 per cent).
Comparison of protocols for diagnosis of appendiceal perforation

No significant differences were observed in sensitivity, specificity, positive and negative predictive value for perforated appendicitis between MRI and US with conditional CT (Table 2). All missed cases of perforated appendicitis cases were identified as simple appendicitis in both imaging protocols.

Both strategies had a low positive predictive value for perforated appendicitis; more than 30% of positive findings were false positive.

Diagnostic accuracy for acute appendicitis (simple or perforated)

US with conditional CT had a positive predictive value for simple or perforated appendicitis of 92 per cent (115/125; 95%c.i.: 86 to 96) and a negative predictive value of 97 per cent (102/105; 95% c.i.: 92 to 99 per cent). MRI performed equally well, with an estimated positive predictive value of 94 per cent (113/120; 95%c.i.: 88 to 97 per cent, \( p = 0.505 \)) and a negative predictive value of 96 per cent (99/103; 95% c.i.: 90 to 98, \( p = 0.682 \)).

MRI features associated with perforated acute appendicitis

Imaging features were available for 210 patients; appendix features of the diffusion weighted series were available in 207 patients (Table 3). Most MRI features that are known to be associated with acute appendicitis were recorded in the majority of both perforated and simple appendicitis cases: an enlarged appendix (30/30 vs. 84/86; \( p = 0.399 \)), peri-appendiceal fat infiltration (29/30 vs. 81/86; \( p = 0.597 \)) and absence of intraluminal air (26/30 vs. 80/86; \( p = 0.285 \)). In cases of appendiceal perforation findings of peri-appendiceal fluid (27/30 vs. 61/86; \( p = 0.036 \)), destruction of the appendiceal wall (14/30 vs. 13/86; \( p < 0.001 \)), presence of an abscess

Table 3. Prevalence and predictive values for perforated appendicitis according to features on magnetic resonance imaging

<table>
<thead>
<tr>
<th>Feature</th>
<th>N</th>
<th>Appendicitis group</th>
<th>Predictive values</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Perf</td>
<td>Simp</td>
<td>No</td>
<td>PPV (%)</td>
</tr>
<tr>
<td>Diameter &gt; 7mm</td>
<td>223</td>
<td>30</td>
<td>87</td>
<td>106</td>
<td></td>
</tr>
<tr>
<td>Peri-appendiceal fat infiltration</td>
<td>210</td>
<td>30</td>
<td>84</td>
<td>86</td>
<td>13 of 94</td>
</tr>
<tr>
<td>Peri-appendiceal fluid</td>
<td>210</td>
<td>29</td>
<td>81</td>
<td>86</td>
<td>8 of 94</td>
</tr>
<tr>
<td>Absence of intraluminal air</td>
<td>210</td>
<td>26</td>
<td>80</td>
<td>86</td>
<td>29 of 94</td>
</tr>
<tr>
<td>Appendicolith</td>
<td>210</td>
<td>16</td>
<td>36</td>
<td>86</td>
<td>4 of 94</td>
</tr>
<tr>
<td>Destruction of the appendiceal wall</td>
<td>210</td>
<td>14</td>
<td>13</td>
<td>86</td>
<td>2 of 94</td>
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<tr>
<td>Abscess</td>
<td>223</td>
<td>10</td>
<td>8</td>
<td>87</td>
<td>1 of 106</td>
</tr>
<tr>
<td>Extra-luminal free air</td>
<td>223</td>
<td>1</td>
<td>0</td>
<td>87</td>
<td>1 of 106</td>
</tr>
<tr>
<td>Restricted diff appendiceal wall</td>
<td>207</td>
<td>27</td>
<td>72</td>
<td>85</td>
<td>5 of 93</td>
</tr>
<tr>
<td>Restricted diff appendiceal lumen</td>
<td>207</td>
<td>24</td>
<td>62</td>
<td>85</td>
<td>8 of 93</td>
</tr>
<tr>
<td>Restricted diff focal collections</td>
<td>207</td>
<td>15</td>
<td>12</td>
<td>85</td>
<td>4 of 93</td>
</tr>
</tbody>
</table>

Values in parentheses are 95 per cent confidence intervals. Data were missing for some features. PPV, positive predictive value; NPV, negative predictive value.
(10/30 vs. 8/86; \( p < 0.001 \)) and restricted diffusion of focal fluid collections (15/14 vs. 12/85; \( p < 0.001 \)) were found more frequent compared to cases of simple appendicitis. Extra luminal air was found in one case of perforated appendicitis, and in one case of acute diverticulitis with a covered perforation (1/30 vs. 0/86; \( p = 0.089 \)).

None of the investigated MRI features had a positive predictive value (PPV) higher than 53 per cent, although the negative predictive value was high (> 87 per cent). The combination of an appendicolith and destruction of the appendiceal wall had the highest PPV of 78 per cent (95% c.i.: 45 to 94 per cent). The second best combination was an appendicolith and restricted diffusion of focal fluid collections with a PPV of 75 per cent (95% c.i.: 41 to 93 per cent). Both combinations were found in only 7/30 and 6/29 of cases with perforated appendicitis.

DISCUSSION

MRI was unable to accurately discriminate between simple and perforated appendicitis. In this respect, it performed similarly poor compared to US with conditional CT. MRI would miss 43 per cent of patients with perforated appendicitis; US with conditional CT would miss 52 per cent of such patients. Although the investigated imaging strategies can adequately detect appendicitis, (all missed cases of perforated appendicitis were identified as having acute appendicitis in both imaging protocols), the accuracy of discrimination between simple and perforated appendicitis seems unacceptably low.

With the prospect of triaging appendicitis cases for antibiotic treatment, one would want to select a group of patients with simple appendicitis. In this study, US with conditional CT selected a group of 103 patients with simple appendicitis, of which 16 had perforated appendicitis (NPV 84 per cent). MRI selected a group of 90 patients with simple appendicitis, in which 13 had perforated appendicitis (NPV 86 per cent). In our opinion too many patients with perforated appendicitis were misclassified as having simple appendicitis. These patients would probably benefit from immediate operation instead of antibiotic treatment only. Triage of appendicitis based on imaging for conservative treatment is inaccurate and may be unsafe. On the other end the high percentage of false positive cases of perforated appendicitis (68 per cent PPV in US with conditional CT, and 57 per cent PPV in MRI) would also lead to inaccurate treatment decisions.

Several limitations need to be addressed. The present study was primarily powered to estimate the sensitivity and specificity for acute appendicitis. Because only 31 patients were diagnosed with perforated appendicitis differences in sensitivity could not be estimated with high precision, which is reflected in the relatively wide confidence intervals.

No direct comparison could be performed between MRI and CT, because of the selective use of CT after inconclusive or negative US. However, a similar conditional strategy with CT seemed to be more sensitive than single use of CT in patients with acute abdominal pain. Also, studies that reported on sensitivity for perforated appendicitis in a single CT strategy showed equally poor results for the discrimination between simple and perforated appendicitis.

The reference standard of appendiceal perforation was subject to the completeness of observation during surgery, as well as to the thoroughness of pathologic evaluation of
the appendix specimen. To achieve the most optimal final diagnosis on perforated acute appendicitis, the expert panel was provided with all relevant information of clinical, laboratory evaluation, results of ultrasound and CT, perioperative findings, histopathology and follow-up. A disadvantage of this design is that imaging results of ultrasound and CT was part of the information provided to the expert panel; this may have caused an incorporation bias for the accuracy of US with additional CT. In practice, the decision of the expert panel was based on peri-operative findings and histopathology in most cases.

The MR protocol that was used in the present study did not comprise a gradient echo sequence. In-phase and opposed-phase gradient echo images may help demonstrate perforated appendicitis due to the characteristic blooming susceptibility effect that occurs on the in-phase images compared to the opposed-phase images in the presence of air. However, only few cases of perforated appendicitis demonstrate extra luminal gas. A relative limitation of our MRI protocol was the lack of intravenous or oral contrast material; a focal defect in the enhancement of the appendiceal wall has been associated with perforated appendicitis in CT-scans in previous studies. Most of the MRI features investigated in this study were significantly associated with perforated appendicitis, but none of them had a sufficiently high positive predictive value to be discriminative. Because there were only 31 patients with appendiceal perforation in the present study, statistical power was not high enough for developing a solid multivariable model to predict perforation on the basis of imaging features. A prediction model based on a combination of clinical and imaging features may improve the diagnostic accuracy of imaging in detecting perforated acute appendicitis. Studies with a larger sample size than ours are needed for such a model. These are currently unavailable in literature; we found only one study that constructed a regression model that correlated CT features with the histological severity of appendicitis. In that study 105 patients had an appendectomy.

Clinical and imaging features of perforated appendicitis have been frequently analysed individually in univariable analysis. Two retrospective studies assessed clinical features in patients that had an appendectomy to differentiate simple from perforated appendicitis. C-reactive protein level and duration of abdominal pain were labelled as strong predictors of perforated acute appendicitis in both studies. Other studies specifically focused on imaging findings and the diagnosis of perforated appendicitis. One study assessed US in patients with appendicitis and found that a visible appendix, abscess, local free fluid and presence of an appendicolith were associated with perforation. The use of CT to distinguish perforated from simple appendicitis has been assessed by multiple investigators in small retrospective studies in patients with surgically proven appendicitis: the presence of an abscess, extra luminal air and an enhancement defect of the appendiceal wall were found to have a low sensitivity but a high specificity for perforated appendicitis. This corresponds to our findings of specific MRI signs with only moderate sensitivity in identifying appendiceal perforation; abscess, extra luminal free air and destruction of the appendiceal wall. However, the combination of an appendicolith and ‘destruction of the appendiceal wall’ or ‘restricted diffusion of focal fluid collections’ corresponded to a probability of perforated appendicitis of at least 75%. In patients with perforated appendicitis an enlarged appendix diameter, peri-appendiceal infiltration and fluid and absence of intraluminal gas were
frequently recorded, but these signs were also observed in a substantial number of patients with appendicitis without surgical or pathologic findings of perforation.

Although MRI of the abdomen has been demonstrated to accurately diagnose appendicitis and to differentiate appendicitis from other causes of acute abdominal pain, the reliability of MRI to differentiate perforated from simple appendicitis is unsatisfactory. Triage of appendicitis patients based on imaging, whether with MRI or US with conditional CT, is still far from perfect.
REFERENCES


DISCRIMINATION BETWEEN SIMPLE AND PERFORATED APPEN DICITIS


## APPENDIX A

### Imaging features

<table>
<thead>
<tr>
<th>Feature</th>
<th>YES / NO</th>
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<tbody>
<tr>
<td>Appendix visualised</td>
<td>YES / NO</td>
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<tr>
<td>Diameter &gt; 7mm</td>
<td>YES / NO</td>
</tr>
<tr>
<td>Peri-appendiceal fat infiltration</td>
<td>YES / NO</td>
</tr>
<tr>
<td>Peri-appendiceal fluid</td>
<td>YES / NO</td>
</tr>
<tr>
<td>Absence of intraluminal air</td>
<td>YES / NO</td>
</tr>
<tr>
<td>Appendicolith</td>
<td>YES / NO</td>
</tr>
<tr>
<td>Destruction of the appendiceal wall</td>
<td>YES / NO</td>
</tr>
<tr>
<td>Abscess</td>
<td>YES / NO</td>
</tr>
<tr>
<td>Extra-luminal free air</td>
<td>YES / NO</td>
</tr>
<tr>
<td>Restricted diffusion appendiceal wall*</td>
<td>YES / NO</td>
</tr>
<tr>
<td>Restricted diffusion appendiceal lumen*</td>
<td>YES / NO</td>
</tr>
<tr>
<td>Restricted diffusion focal collections*</td>
<td>YES / NO</td>
</tr>
</tbody>
</table>

### Final diagnosis

<table>
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<tr>
<th>Condition</th>
<th>POSITIVE</th>
<th>INCONCLUSIVE</th>
<th>NEGATIVE</th>
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</thead>
<tbody>
<tr>
<td>Appendicitis</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Appendiceal perforation</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

Structured case record form. * = only recorded in MRI