Magnetic resonance imaging in acute appendicitis
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Citation for published version (APA):
Chapter 4

The use of ultrasonography and optional magnetic resonance imaging in patients with suspected appendicitis: effect on the outcome of appendectomy

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Submitted
Abstract

**Objective:** To determine if magnetic resonance imaging (MRI) has supplemental value in patients with suspected acute appendicitis, in whom the initial ultrasound (US) findings are equivocal.

**Materials and methods:** Over a 14-month period, 142 consecutive patients (62 men and 80 women; age range 6-80 years; five of whom were pregnant) clinically suspected of having appendicitis were enrolled in a study to prospectively evaluate suspected appendicitis with abdominal US. The US studies were performed by radiologists experienced in abdominal US. If the US findings were equivocal, a complementary MRI was performed after the patient gave written informed consent. The medical ethical commission of the hospital approved the study. Fast turbo spin-echo breath hold T1, T2, and T2 fat suppression sequences were used in both the coronal and axial planes. MRI and US were performed on a 24-hour basis with a policy to postpone imaging studies ordered between 12 pm and 7 am to the subsequent morning, if the condition of the patient allowed such an operative delay. The imaging results were recorded separately and correlated with clinical follow-up and radiological and histopathological findings as the reference standard.

**Results:** Of the 142 patients, the final diagnosis was acute appendicitis in 65, an alternative diagnosis in 43, and non specific abdominal pain in 34. US examination was true-positive for appendicitis in 57, false-positive in one patient, false-negative in 8 patients, and showed a normal appendix or an alternative diagnosis explaining the clinical condition of the patients in 40 cases. In 36 patients, the US studies were equivocal; meaning no appendix or alternative diagnosis could be identified. When equivocal US studies are excluded from the statistical analysis, the sensitivity and specificity for detecting acute appendicitis was 100% and 98%, respectively, the positive predictive value (PPV) and negative predictive value (NPV) was 98% and 100%, respectively, and accuracy was 99%. In 36 patients in whom the US findings
were equivocal, a subsequent abdominal MRI was performed. MRI was positive for appendicitis in 8 patients. In the remaining 28 patients, MRI showed a normal appendix in 22, an alternative diagnosis in 4, and was equivocal in 2 patients. At follow-up, these 28 patients did not develop appendicitis. The resultant sensitivity, specificity, PPV, and NPV of US and MRI combined were 100%, 99%, 98%, and 100%, respectively, with an accuracy of 99%. In 2 patients, in whom both the MRI and US were equivocal, an unnecessary appendectomy was performed. The negative appendectomy rate was 2/67 (3.3%) and the perforation rate was 8/65 (13%).

**Conclusion:** Sonography could be the first imaging technique in patients clinically suspected of acute appendicitis. MRI is an excellent alternative for computed tomography (CT) scans as a complementary study when US is equivocal.
**Introduction**

Acute appendicitis is the most common cause of acute, abdominal, right lower quadrant pain and emergency abdominal surgery. Traditionally, surgeons have accepted a high negative appendectomy rate of up to a 20% in order to avoid a high number of perforated appendicitis. In clinical practice, the reported rate of false positive diagnoses of appendicitis has been as high as 42% in patients with suspected appendicitis [1-6]. Over the past two decades, US and abdominal CT have been increasingly used in an effort to cut down both the negative appendectomy rate and ill-advised delay, possibly leading to perforation and its sequelae [7].

In the past two decades, numerous studies have shown the reliability of US in excluding or confirming the diagnosis acute appendicitis. It has been reported that when patients suspected of having appendicitis are examined by experienced operators, the sensitivity is 76–91%, specificity 74–100%, positive predictive value (PPV) 71–95%, and negative predictive value (NPV) 76–98% [8-15].

Many studies have shown the added value of CT in patients suspected of appendicitis. CT has impressive values for specificity, sensitivity, PPV, and NPV above 90% for detecting and excluding appendicitis [8, 10-12, 16-18]. With modern CT scanners, the scan time is ultrafast, resulting in fewer motion artifacts, and the resolution is isotropic resulting in multiplanar reformatting without loss of resolution. As a result, the values for specificity, sensitivity, PPV, and NPV are above 95% [19].

One of the major disadvantages of CT is the considerable amount of radiation that is involved. A typical dose for an abdominal CT examination is about 10 mSv, implying that one CT examination equals the radiation risk of 500 chest radiographs [20, 21]. A recent article emphasized the increasing source of radiation exposure from CT in the general population [22]. Avoiding radiation exposure is, of course, especially important in young patients and pregnant women.

MRI may be an accurate alternative imaging modality that can be used in place
of CT in selected patients. Detection of appendicitis with MRI has been reported in relatively small groups of both pregnant and non-pregnant patients or in groups in whom patient selection was such that only a small number of patients actually had appendicitis [23-30]. To our knowledge, there are no studies in which MRI was used as an additional technique for problem solving after an equivocal US.

The aim of our study was to determine the benefit of a follow up MRI after an inconclusive US imaging result in patients with clinically suspected appendicitis.

Materials and Methods

Patients
One hundred-forty-two consecutive patients (80 females, 62 males; age range 6–80 years) with clinically suspected appendicitis were prospectively enrolled in this study at our institution (a 350-bed community hospital) between February 2005 and March 2006. Patients were directly referred to the radiology department by the emergency department physician. All 142 patients underwent an abdominal US, as is the policy of our hospital for patients with suspected appendicitis. The US was equivocal in 36 patients. In these 36, an abdominal MRI examination was performed. The US examination was deemed equivocal if the appendix could not be visualized at all and no alternative condition was found. The medical ethical commission of the hospital approved the study, and written informed consent was obtained from all patients prior to the MRI examination, or from the patient’s parents for those younger than 18 years of age.

US examination
The US studies were performed on a Siemens Elegra (Siemens, Erlangen, Germany). The entire abdomen was examined using a 3.5 MHz and 5.0 MHz sector, and 7.5 MHz linear-array transducers. The US criterion for appendicitis was an enlarged,
non-compressible appendix with a diameter of 7 mm or more on US [15, 31]. The US studies were performed by radiologists with more than five years of experience in abdominal US. Routinely, the entire abdomen was examined. There were four possible US results: (1) acute appendicitis; (2) normal appendix visualized, but no alternative condition detected; (3) finding of an alternative condition that explained the clinical symptoms, with or without the demonstration of a normal appendix; or (4) equivocal; the appendix was not visualized and no alternative condition was detected.

**MRI Technique**

All MRI examinations were performed on a 1.0 T system (Siemens, Erlangen, Germany). Breath hold T1-weighted FLASH (TR 133msec/TE5.5 msec/flipangle 75), T2-weighted TSE (3300/108/160), and T2-weighted TSE fat suppression (3360/108/160) sequences were obtained using a body-phased array receiver coil. A multislice imaging technique was used for all patients with 5 mm thick slices with a distant factor of 0.5 mm and acquisition times of 13–24 sec. The FOV chosen was as small as possible, ranging from 260–400 mm and was dependent on the patient’s habitus. First, six scout images were obtained. Then, T2TSE-weighted slices were obtained in the coronal plane in the region where the ileocecal region was expected from the scout images. Sequences were made in the axial plane centered on the region of interest. Because we used a basic MRI protocol consisting of only T1, T2, and T2 fat suppression breath hold sequences, the average MRI examination was completed within 20 minutes of room time.

**MRI interpretation**

The MRI criteria for appendicitis were an enlarged appendix with a diameter of 7 mm or more and signs of periappendiceal inflammatory changes, such as fat stranding. The MRI criteria that excluded appendicitis were a normal appendix of 6 mm or
less, or an appendix with a diameter of more than 6 mm without evidence of peri-
appendiceal inflammatory changes [25, 27].

All US studies were performed as soon as possible after the request from the
emergency department clinician was made, and all US studies were performed
within 7 hours of the request (time range 0.1–7 h) with a median time of less than
one hour. The MRI studies were all performed within one hour of the conclusion of
the US studies. MRI and US were performed on a 24-hour basis with a policy to
postpone imaging studies ordered between 12 am and 7 am to the following morning
if the condition of the patient allowed such an operative delay. It is the policy of our
hospital not to operate on patients after midnight unless the patient is very ill. During
the study period, no patient clinically suspected of appendicitis was admitted for
emergency imaging or underwent surgery for appendicitis between midnight and 7
am.

In the clinical setting, the MRI studies were prospectively interpreted by one of
three participating radiologists with at least five years experience in cross-sectional
abdominal imaging, and who were aware of the US results. The MRI results were
separated into the same 4 categories as the US results; (1) acute appendicitis; (2)
normal appendix visualized, but no alternative condition detected; (3) alternative
condition found that explained the clinical symptoms, with or without the demonstration
of a normal appendix; or (4) equivocal: the appendix was not visualized and no
alternative condition was detected. Hereafter, the combined results of US and MRI
were categorized accordingly.

**Histopathology**

The pathological criteria for acute appendicitis were the presence of polymorphic
granulocytes throughout the appendiceal wall, including the muscularis [32].
Perforation was defined as a peroperatively confined, macroscopic hole in the
appendix and/or the presence of pus or feces in the abdominal cavity [32].
Patients who did not undergo surgery were sent home and were followed-up clinically with at least one visit to the outpatient clinic within 1 week. None of these patients developed appendicitis or complications of a possibly missed appendicitis during a follow-up period of at least 2 years.

Statistical analysis

True-positive cases were those with a positive imaging diagnosis (US plus MRI) for appendicitis and histopathological confirmation. True–negative results were those with negative imaging results for appendicitis or an alternative diagnosis, and who did not develop appendicitis at follow-up. The sensitivity, specificity, PPV, NPV, and accuracy in detecting acute appendicitis were calculated.

<table>
<thead>
<tr>
<th>US-results</th>
<th>Final diagnosis</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Appendicitis</td>
<td>alternative diagnosis</td>
<td>NSAP</td>
<td>Total</td>
</tr>
<tr>
<td>appendicitis</td>
<td>57</td>
<td>1</td>
<td></td>
<td>58</td>
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<td>normal appendix, no alt. diagnosis</td>
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<td></td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>alternative diagnosis</td>
<td></td>
<td>38</td>
<td></td>
<td>38</td>
</tr>
<tr>
<td>equivocal</td>
<td>8</td>
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</tr>
<tr>
<td>Total</td>
<td>65</td>
<td>43</td>
<td>34</td>
<td>142</td>
</tr>
</tbody>
</table>

Table 1: US results in relation to the final diagnosis in 142 patients clinically suspected of appendicitis.

NSAP = non specific abdominal pain.

Results

Of the 142 patients, the final diagnosis was acute appendicitis in 65, an alternative diagnosis in 43, and nonspecific abdominal pain (NSAP) in 34. Eight patients had a perforated appendicitis at surgery. Of the 77 patients who did not have appendicitis, two patients underwent appendectomy: histology confirmed a noninflamed appendix. In the remaining 75 patients, the symptoms resolved and no patient in this group had appendicitis during the follow-up period and none underwent surgery (2–4 years).
**US results**

The US findings were interpreted as positive for appendicitis in 58 patients. In 57, the diagnosis was confirmed by subsequent surgery and pathology. One patient, in whom US showed an enlarged appendix, turned out to have acute pancreatitis and received no surgery. This patient had an enlarged appendix of 8 mm with signs of periappendical inflammation and some fluid around the appendix was found. Local irritation from pancreatic fluid, in all probability, caused secondary thickening of the appendix resulting in a false-positive diagnosis. The diagnosis of pancreatitis was made on clinical and biochemical grounds shortly after the US examination, and an unnecessary appendectomy was avoided.

US findings showed a normal appendix in 10 patients, an alternative diagnosis in 29, a combination of a normal appendix with an alternative diagnosis in 9 patients, and an equivocal result in 36 patients (Table 1). If an equivocal US was deemed negative for appendicitis, the sensitivity and specificity for detecting acute appendicitis were 88% and 99%, respectively, PPV and NPV were 98% and 90%, respectively, and accuracy was 94%. If an equivocal US was deemed positive for appendicitis, then the sensitivity and specificity for detecting acute appendicitis would be 100% and 62%, respectively, the PPV and NPV would be 69% and 100%, respectively, and the accuracy would be 80%. However, because this was an intent-to-treat analysis and patients with an equivocal result would need further diagnostic testing, it was difficult to consider the equivocal US as negative or positive for appendicitis. When equivocal US studies were excluded from the statistical analysis, the sensitivity and specificity for detecting acute appendicitis with US would be 100% and 98%, respectively, the PPV and NPV would be 98% and 100%, respectively, and the accuracy would be 99%. The median diameter of the inflamed appendix was 9 mm (7–20 mm). In 19 patients, a normal appendix could be seen with a median diameter of 4.5 mm (3–8 mm). In 9 of these patients, an alternative diagnosis was determined as well. In the group of patients without appendicitis, an alternative diagnosis was made in 38
In 36 patients, the US showed no abnormalities and also did not visualize the appendix; therefore, the result was deemed equivocal. The US results were equivocal because of obesity or because of a retrocecal or deep pelvic position of the appendix, or a combination of factors.

### Table 2: Alternative diagnoses in 42 patients, as demonstrated by US (n=38) and MRI (n=4).

<table>
<thead>
<tr>
<th>Diagnosis</th>
<th>US</th>
<th>MRI</th>
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</thead>
<tbody>
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<td><strong>Gynecological</strong></td>
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<td></td>
</tr>
<tr>
<td>Tuboovarian abscess</td>
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<td></td>
</tr>
<tr>
<td>Ovarian torsion</td>
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<td>1</td>
</tr>
<tr>
<td><strong>Urologic</strong></td>
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<td></td>
</tr>
<tr>
<td>Hydronephrosis</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Ureteral stones</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Pyelonephritis</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td><strong>Gastroenterologic</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mesenteric adenitis</td>
<td>8</td>
<td>1</td>
</tr>
<tr>
<td>Ileocecal intussusception</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Terminal ileitis (bacterial or Crohn)</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Cecal carcinoma</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Cecal diverticulitis</td>
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<td></td>
</tr>
<tr>
<td>Sigmoid diverticulitis</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Omental infarction</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Epiploic appendagitis</td>
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<td></td>
</tr>
<tr>
<td>Non-palpable rectus sheath hematoma</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Cholecystitis</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>38</td>
<td>4</td>
</tr>
</tbody>
</table>

**MRI results**

In the 36 patients with equivocal US results, an abdominal MRI was performed which showed acute appendicitis in 8 (Fig 1), a normal appendix in 22 (Fig 2), and an alternative diagnosis in 4. When the overall results were considered, including patients who had US only and who had US and MRI, the findings were acute appendicitis
in 66, a normal appendix without an alternative diagnosis in 32, and an alternative
diagnosis in 42 (Table 3). Combined US and MRI were inconclusive in 2 patients.
In these 2 patients, neither US nor MRI demonstrated the appendix; however, no
secondary signs of appendicitis were seen. In both patients, an appendectomy was
performed on clinical grounds, and in both cases a normal appendix was removed
resulting in a negative appendectomy rate of 3%.

**Fig. 1**– 39-year-old man with suspected appendicitis in which US was equivocal due to obesity.
Coronal T1- (a), T2- (b) and T2-fatsuppression (c) weighted images show a 13 mm enlarged appendix
(arrow) with signs of periappendicitis (arrowheads in a and c) in the form of low intensity strands in the
mesenteric fatty tissue surrounding the appendix in a and in the form of areas with high intensity in
the surrounding mesenteric fat in c. In b, parts of a disintegrated appendicolith is seen (small arrows).
Appendicitis without perforation was confirmed at surgery and by pathology.
When the US and MRI results were combined and the 2 inconclusive results were deemed negative, the sensitivity and specificity for detecting acute appendicitis was 100% and 99%, respectively, with a PPV and NPV of 98% and 100%, respectively, and an accuracy of 99%. If the 2 inconclusive results were deemed positive for appendicitis, then the sensitivity and specificity for detecting acute appendicitis would be 100% and 96%, respectively, with a PPV and NPV of 96% and 100%, respectively, and an accuracy of 98%.

There were 8 patients with a perforated appendicitis in the group of 65 patients who had appendicitis, resulting in a perforation rate of 13%. In the 8 patients with appendicitis in whom the inflamed appendix was not visualized with US and the correct diagnosis was made with MRI, the reason for the inability to visualize the
appendix with US was a retrocecal position of the appendix (n = 1), a deep pelvic location (n = 1), and obesity (n = 6).

<table>
<thead>
<tr>
<th>Combined US+MRI results</th>
<th>Final diagnosis</th>
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<tbody>
<tr>
<td></td>
<td>appendicitis</td>
<td>alternative diagnosis</td>
<td>NSAP</td>
<td>Total</td>
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<td></td>
<td>66</td>
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<tr>
<td>normal appendix, no alt. diagnosis</td>
<td></td>
<td></td>
<td>32</td>
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<tr>
<td>alternative diagnosis</td>
<td></td>
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<tr>
<td>equivocal</td>
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<td></td>
<td>2</td>
</tr>
<tr>
<td>Total</td>
<td>65</td>
<td>43</td>
<td>34</td>
<td>142</td>
</tr>
</tbody>
</table>

Table 3: Combined US and MRI results in relation to the final diagnosis in 142 patients clinically suspected of appendicitis. NSAP = non specific abdominal pain.

In our group of patients, there were 38 patients younger than 20 years of age (6–20 years), and 5 pregnant patients. Of the 38 young patients, US did not show a normal or inflamed appendix or an alternative diagnosis in 10. Of the 5 pregnant patients, US was nondiagnostic in 4. In three pregnant patients, a normal appendix could be seen with MRI and an alternative diagnosis could also be made. In one pregnant patient, where the appendix could not be seen with US, MRI showed appendicitis (Fig. 3). The MRI study prevented an unnecessary operation in 3 pregnant patients by demonstrating a normal appendix.

In the 10 young patients (8–18 years) in whom the US study was equivocal, MRI examination showed a normal appendix in 5, an alternative diagnosis in 2, and an inflamed appendix in 2. In one young patient, in whom neither MRI nor US could depict the appendix or an alternative diagnosis, an appendectomy was performed and a normal appendix was removed.
Fig. 3—21-year-old woman who was 20 weeks pregnant and experiencing progressive pain in the RLQ, possibly appendicitis. Due to the large abdomen, US was equivocal. Coronal (a) and transverse (b) T2-weighted images with fat suppression show an enlarged appendix (arrow) filled with fluid and two appendicoliths. At operation and pathology, an uncomplicated appendicitis was found.

Discussion

In the past two decades, numerous studies have shown the reliability of US in excluding or confirming the diagnosis of acute appendicitis. It has been reported that when patients suspected of having appendicitis are examined by experienced operators, the sensitivity is 76–91%, the specificity is 74–100%, the PPV is 71–95%, and the NPV is 76–98% [8-15]. In these studies, non-visualization of the appendix with US in cases of surgically proven appendicitis is deemed a false-negative test result, although appendicitis cannot be ruled out by US in these cases. Some false-positive results occurred when US showed appendicitis, but the symptoms resolved and no surgery was performed, although these cases could have been due to spontaneously resolving appendicitis. It is often argued that US is too operator-dependent for the referring physician to rely on. As US equipment improves and experience is gained as part of residency training, one can debate whether this argument is valid in the evaluation of patients with abdominal symptoms. In a recent
prospective study comparing US and CT in patients clinically suspected of having appendicitis, there was no significant difference in the diagnostic accuracy between US and CT, or between groups of radiologists, regardless of patient age, sex, or body mass index. The frequency of inconclusive examinations, however, was significantly higher with US than with CT, regardless of the radiologist’s experience [10].

The major advantages of US are its widespread availability, low cost, and lack of radiation. In a recent study, US was advocated as the first imaging technique in adult patients with suspected appendicitis, with CT only recommended in patients with an equivocal US result [33]. In patients with suspected acute appendicitis, an US examination with the option of additional CT significantly lowers the negative appendectomy rate compared with clinical acumen alone, without adverse effects on the perforation rate or the in-hospital delay [34].

CT has impressive values for specificity, sensitivity, PPV, and NPV that are above 90% for detecting and excluding appendicitis [8, 10-12, 16-18]. It is cost-effective in the evaluation of patients with RLQ pain [18, 35]. With modern CT scanners, the scanning time is ultrafast, allowing for less motion artifacts; the resolution is isotropic resulting in multiplanar reformatting without loss of resolution. As a result, the values for specificity, sensitivity, PPV, and NPV are above 95% [19], and this has caused many institutions to utilize CT as a first line test.

A major disadvantage of CT is the considerable radiation dose, which is especially important in children, young adults, and pregnant patients. A typical dose for an abdominal CT examination is on the order of 10–15 mSv [21]. An effective dose of 10 mSv corresponds to an excess risk of radiation-induced cancer for a 25 year old of about 1 in 900. The risk of fatal cancer induction is about 1 in 1800 [21, 36, 37]. In pregnant women, a single abdominal CT scan involves risk to the fetus; the risk of cancer is approximately 1 in 200, and the risk of fatal cancer is 1 in 400 [36, 37]. This risk can be seen in proportion to the lifetime cancer risk as well, and in this respect is relatively small, but not negligible. The routine use of diagnostic CT
examinations for benign diseases, like appendicitis, gives rise to the question of whether the diagnosis could be obtained by other radiological means, especially in pregnant women and young patients [20].

There are a number of strategies to limit radiation dose, including performing only necessary examinations, limiting the region of coverage, and adjusting individual CT settings based on indication, region imaged, and size of the child or patient. The International Commission on Radiological Protection (ICRP) recently published a report on radiation and pregnancy. This report recommended that if the expected dose for the fetus is high, as in abdominal or pelvic CT, one should consider whether the diagnosis could be obtained without the use of ionizing radiation [20, 38].

MRI has been reported to provide good results in excluding or detecting appendicitis [23-27, 29, 30]. In one of these studies, a series of 118 patients, 11 of whom had acute appendicitis, MRI had a sensitivity of 90%, a specificity of 98%, a PPV of 81%, and a NPV of 99% [30]. These and other similar results support the use of MRI in pregnancy when there is a clinical suspicion of acute appendicitis and an inconclusive US examination. Our study confirms that the combined use of US and optional MRI yields excellent diagnostic results, and markedly decreases the negative appendectomy rate without increasing the perforation rate. All in all, there was one false positive diagnosis of appendicitis and two patients in whom both US and MRI were equivocal who eventually had an unnecessary appendectomy, resulting in a negative appendectomy rate of 3%.

There were 8 patients with perforated appendicitis in the group of 65 patients with appendicitis, resulting in a perforation rate of 13%, which is low compared with rates reported in surgical surveys (10–28%) [39-42]. In 30 patients, it was not possible to visualize the inflamed or normal appendix with US, but MRI showed a normal appendix in 22 and an inflamed appendix in 8. The reason for the non-visualization of the appendix with US was a retrocecal position of the appendix, a deep pelvic location, obesity, or a combination of these. Other studies confirm a high sensitivity
and specificity for detecting a normal or abnormal appendix with MRI as well [24-27, 43].

In our group of patients, there were 10 patients younger than 20 years of age (6–20 years) and 4 pregnant patients in whom the US was non-diagnostic. In these 14 patients, CT could have been the next step, but as this study shows, MRI was a good alternative. It showed a normal appendix in 8, appendicitis in 3, an alternative diagnosis in 2, and remained inconclusive in one patient, resulting in one negative appendectomy.

In the past decade, MRI has emerged as a useful imaging modality for the evaluation of the gastrointestinal tract [29, 44]. The major advantages over CT are the lack of ionizing radiation and the higher intrinsic contrast resolution. Initially, the MRI techniques were relative slow, preventing abdominal MRI in acute settings. However, the introduction of rapid sequences and improved hardware led to sequences that could visualize the abdomen in one breath hold. This has paved the way for MRI in acute diseases. MRI is gradually being introduced as a complementary imaging modality to CT in the diagnosis of patients with abdominal pain [24, 26, 29, 30, 45-49].

There are no known biological risks associated with MRI, even with high magnetic fields in laboratory settings in animal studies. To our knowledge, no delayed sequelae from undergoing or performing MRI examinations have been encountered, and it is expected that the risk of delayed sequelae is extremely small. The risk of exposing the developing fetus or young patient to any radiological diagnostic imaging technique that uses ionizing radiation is probably greater than the theoretical risk of MRI. According to the Safety Committee of the Society for Magnetic Resonance Imaging, MRI is indicated for use in pregnant women when the result of nonionizing diagnostic imaging, such as US, is inadequate for diagnosis or when MRI is expected to provide important information for proper treatment of the fetus or mother [36, 37].
A frequently encountered problem of MRI is its availability, especially during off hours. For many institutions, the staffing issues around providing such a service means it is not always available, leaving ultrasound and CT as the only practical options available. This is the reason why in this study a simple imaging protocol of T1, T2, and T2 fat-suppression breath hold sequences was used. These sequences are quick and easy to use and learn and, as this study indicates, are sufficient to detect or rule out appendicitis. Perhaps by making the use of MRI more user-friendly, it will indeed be used more often during off hours.

Other limitations of MRI include poorer spatial resolution compared with CT, increased sensitivity to motion-related artifacts, and limited compatibility with equipment used in intensive care and in the monitoring of patients. CT is many times faster than MRI, even when the latter is performed with fast gradient-echo sequences. Therefore, CT is more suitable for diagnostic imaging of an acutely ill patient who may be unable to cooperate and lie still for the duration of MRI acquisition. Finally, most radiologists are more familiar with the appearance of acute abdominal and pelvic conditions on CT scans than they are with the MRI imaging features.

In our study we used a MRI protocol focused on the appendiceal or ileocecal region. In CT studies, scanning the entire abdomen instead of only the appendiceal region yields a higher diagnostic result by detecting more alternative diagnoses or an appendix in an atypical position, explaining the clinical condition of the patient [17, 50]. This study, however, was designed to determine the value of MRI as an additional tool to resolve equivocal US results. The US studies of the entire abdomen were routinely performed, which could detect or rule out many differential diagnoses of appendicitis.

Another disadvantage of imaging strategies could be the additional cost involved. However, pre-operative imaging in patients clinically suspected of appendicitis prevents unnecessary relatively expensive operations, hospitalizations, or diagnostic delays and associated complications such that they are cost-effective [18, 35].
In conclusion, our study demonstrates that an abdominal MRI in the evaluation of patients suspected of having appendicitis is a safe and reliable alternative to CT in patients in whom US is equivocal.
References

41. Colson M, Skinner KA, Dunnington G. High negative appendectomy rates are no longer acceptable. *Am J Surg* 1997;174:723-726; discussion 726-727


