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Accuracy of unenhanced, non-sedated MRI in the diagnosis of acute appendicitis in children.

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Abstract

Non–contrast-enhanced MRI can be an effective initial imaging technique in children suspected of having acute appendicitis, with high sensitivity, specificity, and accuracy for detection of acute appendicitis and potential to depict clinically relevant alternative diagnostic findings.

Methods

Total 370 patients were recruited for this study. MRI reports were correlated with pathology reports in cases that underwent appendectomy and with clinical outcomes if no operation was done. 370, non-sedated MRIs were done and reviewed with median age: 13 years. Sixty-five (18.6%) MRIs were positive for appendicitis, and 62 of those underwent appendectomy (3 excluded clinically). Pathology was positive in 59/62 cases. 256 (73.1%) MRIs were negative for appendicitis. Six cases underwent appendectomy (persistent symptoms). Pathology was positive in 2/6 cases. The overall diagnostic accuracy was: sensitivity 96.6% (95% CI: 88.6–99.6), specificity 97.8% (95% CI: 95.0–99.1), PPV: 90.8% (95% CI: 81.6–95.6; false positives 6/65), and NPV: 99.3% (95% CI: 97.0–99.8; false negatives 2/254). Twenty-eight (8.3%) MRIs were non-diagnostic. None of those 28 cases had appendicitis (3 negative pathology, 25 excluded clinically).

Conclusions: The unenhanced, non-sedated MRI is highly preferred for the diagnosis of appendicitis in children. It should be considered as an alternative to CT of patients with suspected appendicitis to exclude the risks associated with ionizing radiation.

Keywords: MRI, HASTE, DWI.

Introduction

The most common cause of acute right lower quadrant abdominal pain in children is acute appendicitis (1). Selecting the appropriate imaging technique is critical for the timely and accurate diagnosis of acute appendicitis. The American College of Radiology (ACR) has published appropriateness criteria for imaging that have been widely adopted, and these evidence-based guidelines recommend US as the initial imaging modality of choice in the pediatric population (2). US has several advantages that makes it the preferred primary modality, including the absence of ionizing radiation, the absence of the need for sedation, availability, low cost, and high positive predictive value (3). Disadvantages of US include dependence on operator skill, limited evaluation for alternative diagnoses and complications, and low negative predictive value (4). Additionally, wide variability exists in reported US sensitivity for the diagnosis of acute appendicitis, ranging from 30%–98.5% (5). When US

results are unsatisfactory or equivocal, the ACR recommends using advanced cross-sectional imaging. CT has been performed as a subsequent test owing to higher accuracy than US, in addition to the access and speed of the study (6). CT has also been recommended as an appropriate first-line test in certain situations. However, the use of CT in the pediatric population has been questioned and moderated because of concerns over the potential negative effects of ionizing radiation and the potential need for oral and/or intravenous contrast material (7). MRI overcomes these shortcomings of CT. Advances in MRI have enabled rapid, free-breathing imaging without the need for intravenous or oral contrast material, allowing for a more efficient, comprehensive evaluation of symptom etiology, which may be especially challenging to elicit clinically in a pediatric population. This has resulted in modest increased utilization of MRI as a second-line imaging modality in children as an alternative to CT, with the reported diagnostic accuracy of MRI similar to that of contrast material–enhanced CT (8). However, MRI is not routinely used as the primary imaging modality. The purpose of our study was to evaluate the accuracy of unenhanced, non-sedated MRI in the diagnosis of acute appendicitis in children

Materials and methods

A retrospective review of all MRIs suspected for acute appendicitis was done. Patients did not receive antibiotics for presumed appendicitis prior to the MRI study. Patients were 18 years of age or younger. An informed consent was signed after explaining the reason of this study. Data was collected after the approval of Institutional review board.

Imaging protocol and interpretation

US and CT were considered non-diagnostic if the appendix was not visualized, or was partially visualized appearing normal, but with the presence of secondary signs such as peri-appendiceal fat stranding or free fluid (among others) in the RLQ. All MRI studies were done in a 1.5 or a 3 Tesla MR magnet, with an abbreviated protocol: coronal T2 HASTE with and without fat suppression, axial T2 HASTE with and without fat suppression, and axial DWI (Fig. 1). All MRI studies were performed without contrast and without sedation. Our hospital is equipped with 24/7/365 MRI availability, so there was no delay in care due to MRI scheduling limitations. All MRI studies were read by the on-call attending radiologist immediately after the study was completed. MRIs were considered positive for appendicitis if the following features were seen: distended appendix (diameter N6 mm), presence of periappendiceal inflammatory changes, fluid or abscess, and positive restricted diffusion on DWI.

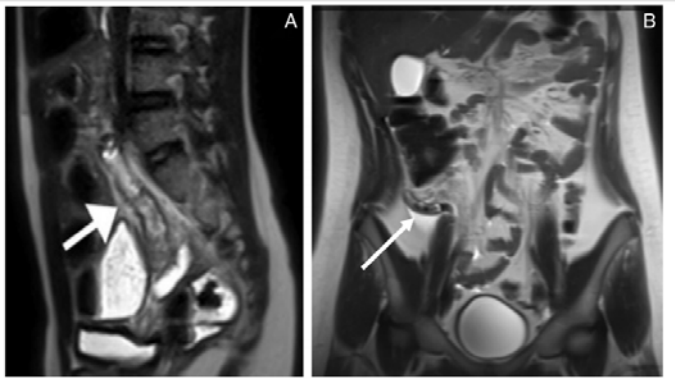

Fig. 1. A: Sagittal HASTE demonstrates a distended appendix (arrow) measuring more than 6 mm in width, with an appendicolith at its cephalad tip. There is periappendiceal mesenteric haziness denoting inflammatory changes. B: Coronal fluid sensitive image shows a distended appendix (arrow) containing at least two appendicoliths manifested as flow voids, surrounded by T2 hyper intense inflammatory changes and fluid.

Outcome and statistical analysis

All patients with suspected appendicitis underwent laparoscopic appendectomy. No patient was treated for suspected appendicitis nonoperatively. MRI reports positive for appendicitis were correlated with pathology reports following appendectomy. MRI reports negative for

appendicitis were correlated with clinical outcomes for a 30-day period after the MRI date. Data are expressed as median (range) or mean (SD).

Results

A total of 370 unenhanced, non-sedated MRI studies were done and reviewed during the analyzed period. The mean age was 13 years. There were 206 (58.9%) girls and 164 (41.1%) boys. A total of 65 (18.6%) MRIs were positive for appendicitis. Of those 65 cases, 62 underwent appendectomy and 3 did not undergo an operation due to a low clinical suspicion. None of these 3 patients had acute appendicitis (all followed clinically for 30 days). Pathology was positive for appendicitis in 59 of the 62 (95.2%) and negative for appendicitis in 3 of the 62 (4.8%) cases that underwent appendectomy. The false positive rate of the MRI study was therefore 6/65 (9.2%). A total of 183 (73.1%) MRIs were negative for appendicitis. Six of those patients underwent appendectomy anyway based on the clinical suspicion, despite the negative MRI. In 2 of those cases the pathology was positive for appendicitis. In the other 4 cases the pathology was negative for appendicitis. None of the 183 patients who had an MRI negative for appendicitis and did not undergo an operation had acute appendicitis (followed clinically for 30 days). The false negative rate of the MRI was 2/183 (0.8%). The sensitivity of the unenhanced, non-sedated MRI for the diagnosis of acute appendicitis was 96.7% (95% CI: 88.6–99.6). The specificity was 97.7% (95% CI: 95.1–99.2%). The positive predictive value was 90.8% (95% CI: 81.7–95.6%; false positives: 6 of 65 [9.2%]), and the negative predictive value was 99.2% (95% CI: 97.0–99.8%; false negatives: 2 of 256 [0.8%]). The overall diagnostic accuracy was 97.5% (95% CI: 95.1–98.9%). There were 29 (8.3%) MRI studies that had a non-diagnostic or an equivocal result: appendix not visualized in 25 cases, appendix only partially visualized in 3 cases, and appendix seen but with indeterminate findings in 1 case. None of those 29 cases showed inflammatory signs in the RLQ. Four of these cases underwent appendectomy based on the clinical suspicion, and the other 25 did not undergo an operation and were not treated with antibiotics. The pathology result of the 4 cases that underwent an appendectomy was negative for acute appendicitis, and none of the 25 patients who did not undergo an operation had acute appendicitis (all followed clinically for 30 days). The mean time spent by the patients on the MRI scanner was 42 (14.1) minutes.

Discussion

In this review we aimed to determine the diagnostic accuracy of a rapid, unenhanced, non-sedated MRI as a second line study for the diagnosis of acute appendicitis in children in a large patient cohort. We found a sensitivity of 96.7%, a specificity of 97.7%, and a negative predictive value of 99.6%, all of which support a high diagnostic accuracy of the study for the intended purpose. The results of our review are similar to previous reports in literature, all of which have smaller patient cohorts or were done with a different study design [9]. Herliczek et al. published a remarkable sensitivity of 100% with no false negative studies in a cohort of 60 cases [10]. Similarly, Dillman et al. reported an outstanding sensitivity of 100%, in a cohort of 103 cases. Kulaylat et al. reported a cohort of 510 unenhanced, non-sedated MRIs done as the primary imaging modality, so all patients being evaluated for suspected appendicitis underwent an MRI, and none of those patients had non-diagnostic results on previous imaging studies [11]. In addition, the most common alternative imaging study was a CT. Despite the differences, Kulaylat's report and our report showed relatively similar findings. Several meta-analyses have been published with compiled data from thousands of patients confirming the high diagnostic accuracy of the MRI for acute appendicitis in children, although those

meta-analysis pooled reports that included contrast-enhanced and unenhanced MRIs, and MRIs done with a variety of different sequences [12]. Our data supports that MRI has a diagnostic performance comparable to that of CT, which according to the American College of Radiology, is still recommended as a second line diagnostic tool in the workup of acute appendicitis in children [13]. Zhang et al. published a metaanalysis comparing pooled sensitivity of US, CT, and MRI. Sensitivity and specificity were 0.89 and 0.97 for ultrasound, 0.95 and 0.92 for CT, and 0.98 and 0.97 for MRI, and there are several other publications in the literature that support this finding [14]. However, do to a variety of reasons that include availability and cost, among others, MRI is still only done in a minority of cases compared to CT, particularly in nonchildren's hospitals [15]. Our study adds to the literature evidence to support the use of MRI as the second line imaging modality in children with suspected acute appendicitis and non-diagnostic ultrasound findings, and we hope that in the near future CT will not be used at all for this purpose. If we divide our cohort by the definitive diagnosis, there were 291 patients without appendicitis and 61 patients with appendicitis. Of the 291 cases with a normal appendix, the appendix was visualized in 266 and not visualized 25, for a visualization rate of the normal appendix of 91.4%. Previous studies have generally reported a lower visualization rate of the normal appendix, from approximately 55% to 81%, depending on the MRI technique [16]. No difference was found related to age or gender in relation to visualization of the appendix in our study, or in any previously published report. We had 29 (8.3%) MRIs with a non-diagnostic result (25 studies with the appendix not visualized; no secondary signs of appendicitis in any of the 29 studies). This 8.3% failure to provide an answer could at first glance argue against the performance of the study. However, none of these 29 patients had acute appendicitis. Our interpretation is that non-visualization of the appendix in the absence of secondary signs of appendicitis, in an appropriately done MRI, has a 100% negative predictive value and should be considered a negative study rather than an inconclusive one. This has also been shown to be the case for US and for CT [17]. The strongest advantage of MRI over CT is the absence of ionizing radiation and its associated risk of malignancy later in life. Even though CT can be done with a reduced dose, the radiation is never zero. The other important advantage is that the MRI protocol used at our institution does not require any type of contrast (neither oral nor intravenous). The use of oral contrast for CT not only increases the waiting time, since it ideally should reach the cecum, but is frequently associated with vomiting and the need for a nasogastric tube for its instillation. In addition, the intravenous CT contrast almost universally used for the diagnosis of appendicitis can be associated with systemic allergic reactions, skin irritation and nephrotoxicity. Potential disadvantages of the MRI are: a longer time spent by the patient in the scanner, the non-compliance of patients to the loud MRI scanner, and a high cost. In regards to the duration of the study, the mean time of our MRI was 42 (14) minutes, which is certainly longer than a standard CT with intravenous contrast (≈10 min). However, if we consider the scanner time within the whole imaging process (i.e. transfer to and from the radiology department, image acquisition, interpretation of the study, and availability of the results), assuming that all the other steps are similar for MRI and CT (as is the case in our hospital) it is difficult to argue that a 30-min difference in the image acquisition has any negative impact on the decision-making process and the eventual clinical outcome. Non-compliance to the study has not been an issue in our experience, which included patients as young as 3 years. Only 3 (0.8%) of our patients were unable to tolerate the

study, and were followed clinically. We do not have data on compliance to our MRI protocol in patients younger than 3 years, although the incidence of appendicitis in that age group is quite low. In regards to the cost of the study, in our institution the costs of an unenhanced MRI with the described protocol are less than the cost of a CT with the protocol specific for appendicitis. The financial cost, however, needs to be contrasted to the potential risks of each study if the accuracy is equivalent.

Conclusion

The unenhanced, non-sedated MRI is a highly accurate second-line study for the diagnosis of acute appendicitis in children who have non-diagnostic results on US, with a sensitivity of 96.7%, a specificity of 97.7%, and a negative predictive value of 99.2%, according to our review of a 370-patient cohort. Our findings support the conclusions that, if at all possible, and provided there is no delay in care, MRI should be considered as an alternative to CT in children with suspected acute appendicitis and non-diagnostic US findings, to eliminate the risks associated with ionizing radiation.

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