RESEARCH ARTICLE

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Diagnostic impact of diffusion weighted imaging in acute appendicitis

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ABSTRACT

Objective: This study reveals the impact of using diffusion-weighted imaging (DWI) to accurately diagnose acute appendicitis as an alternative to CT.

Methods: In our study, 41 patients with suspected acute appendicitis, who had undergone magnetic resonance imaging (MRI) following sonographic (US) evaluation, and been referred to the radiology department during a period of 5 months were included. Two radiologists separately evaluated diffusion-weighted images. A five-range scoring system was used in the evaluation of diffusion MRI for each B-value. Any score that is 3 or higher is considered acute appendicitis. Statistical analysis was performed, and ROC curves were used for comparison.

Results: In our study, 41 patients were examined. After the exclusion of 6 patients, out of the 35 patients (13 women, 22 men; mean age: 34, age range: 16 to 80) included in the study, 19 (46%) underwent surgery, and pathology results confirmed acute appendicitis. The results of all operated patients were consistent with the ultrasonography reports. However, ultrasonography had three false-positive results. Of these patients, two were identified by two observers and one by a single observer as not having appendicitis via DWI. The sensitivity, specificity, positive predictive value, negative predictive value, and accuracy rate for DWI were measured as 52-89%, 50-87.5%, 59-80%, 68-84%, and 65-80%, respectively.

Conclusion: According to our study, with the advancement of technology, we believe that MRI usage in appendicitis will possibly increase, potentially surpassing CT, especially in selected cases due to the absence of radiation dose concerns.

Keywords: Appendicitis, Acute abdomen, Magnetic Resonance Imaging

ÖZET

Akut appendisitte difüzyon ağırlıklı görüntülemenin tanıdaki etkisi

Amaç: Bu çalışma, akut appendisitin kesin tanısında BT'ye alternatif olarak diffüzyon ağırlıklı görüntüleme (DAG) kullanmanın etkisini ortaya koymaktadır.

Yöntem: 5 aylık bir dönemde, akut appendisit şüphesiyle başvuran ve ultrasonografik (US) değerlendirme ardından magnetik rezonans görüntüleme (MRG) yapılmak üzere radyoloji bölümüne yönlendirilen 41 hasta çalışmamıza dahil edildi. İki radyolog, diffüzyon ağırlıklı görüntüleri bağımsız olarak değerlendirdiler. Diffüzyon MRG değerlendirmesinde her B değeri için beş aralıklı bir puanlama sistemi kullanıldı. Puanlama 3 veya daha yüksekse, bu durum akut appendisit olarak kabul edildi. İstatistiksel analiz yapıldı ve karşılaştırmada ROC analizi kullanıldı.

Bulgular: Çalışmamızda 41 hasta incelendi. 6 hastanın çalışmadan çıkartılmasından sonra, 35 hastanın (13 kadın, 22 erkek; ortalama yaş: 34, yaş aralığı: 16 ila 80) 19'u (%46) ameliyat edildi ve patoloji sonuçları akut apandisiti doğruladı. Ameliyat edilen tüm hastaların sonuçları ultrasonografi raporlarıyla uyumluydu. Ancak ultrasonografinin 3 yanlış pozitif sonucu mevcuttu. Bu hastalardan ikisi, iki gözlemci tarafından, biri ise tek gözlemci tarafından DAG ile appendisit olmadığı şeklinde saptanabildi. DAG için sensitivite, spesifite, pozitif prediktif değer, negatif prediktif değer ve doğruluk oranı sırasıyla %52-89, %50-87.5, %59-80, %68-84 ve %65-80 olarak ölçüldü.

Sonuç: Çalışmamıza göre, teknolojinin ilerlemesiyle appendisit vakalarında MRG kullanımının artabileceğini ve özellikle seçili vakalarda radyasyon dozu endişesi olmaması nedeniyle BT'yi potansiyel olarak geçebilece-ğine inanmaktayız.

Anahtar kelimeler: Appendisit, Akut batın, Manyetik Rezonans Görüntüleme

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INTRODUCTION

The leading reason for acute abdominal pain that requires surgical attention is appendicitis [1]. Imaging is critical when it comes to evaluating patients with suspected acute appendicitis, especially in guiding treatment choices and planning for surgery. Currently, computed tomography (CT) is the preferred modality for imaging evaluation in patients with suspected appendicitis. As a result of its high sensitivity, specificity, and rapid accessibility, CT has been proven to be a useful method for diagnosis [2]. Prior research has also demonstrated that CT greatly lessens the expenses for care as well as negative appendectomy rates [3]. However, downsides of CT do include the use of intravenous contrast agents, the possibility of allergic reactions or contrast-induced acute kidney injury, and exposure to ionizing radiation.

Magnetic resonance imaging (MRI) has garnered recent attention since it does not necessitate using intravenous contrast agents, does not involve ionizing radiation, and effectively identifies inflammation. Furthermore, MRI is less affected by patient-specific factors such as large body habitus or technical proficiency compared to ultrasound (US), which provides a significant advantage[4]. The focus of this study is to highlight the benefits and drawbacks of diffusion sequences in MRI, which are critically important for evaluating ischemia in acute appendicitis assessment. DWI offers insights into the biophysical traits of tissues, an example being microstructure, microcirculation, and cell structure, as well as enabling the characterization of biological tissues through water molecule diffusion characteristics. The diffusion coefficient measures the degree of molecular mobility at a microscopic level.

In our study, we investigated the contribution of diffusion-weighted MRI with low b-values (200-400-600 s/mm2) in identifying acute appendicitis among patients with suspected cases.

MATERIALS and METHODS

Patient Selection: Our study comprised a total of 41 patients who underwent a lower abdominal MRI with a preliminary acute appendicitis diagnosis between January and May 2010. Based on biochemical and physical examination findings, an ultrasound was performed. Due to inconclusive ultrasound results, an MRI was conducted with a preliminary diagnosis of appendicitis (Figure 1). The patients' data were retrospectively reviewed from the database. After obtaining approval from the ethics committee for the study design, written informed consent was obtained from every participating patient.

MRI Technique: A 1.5 Tesla MRI unit (Excite 2.0, GE MEDICAL SYSTEMS) with an 8-channel body coil was used. Sedation and anesthesia were not administered to the patients. Contrast agents were not administered. Routine MRI sequences included T2-.

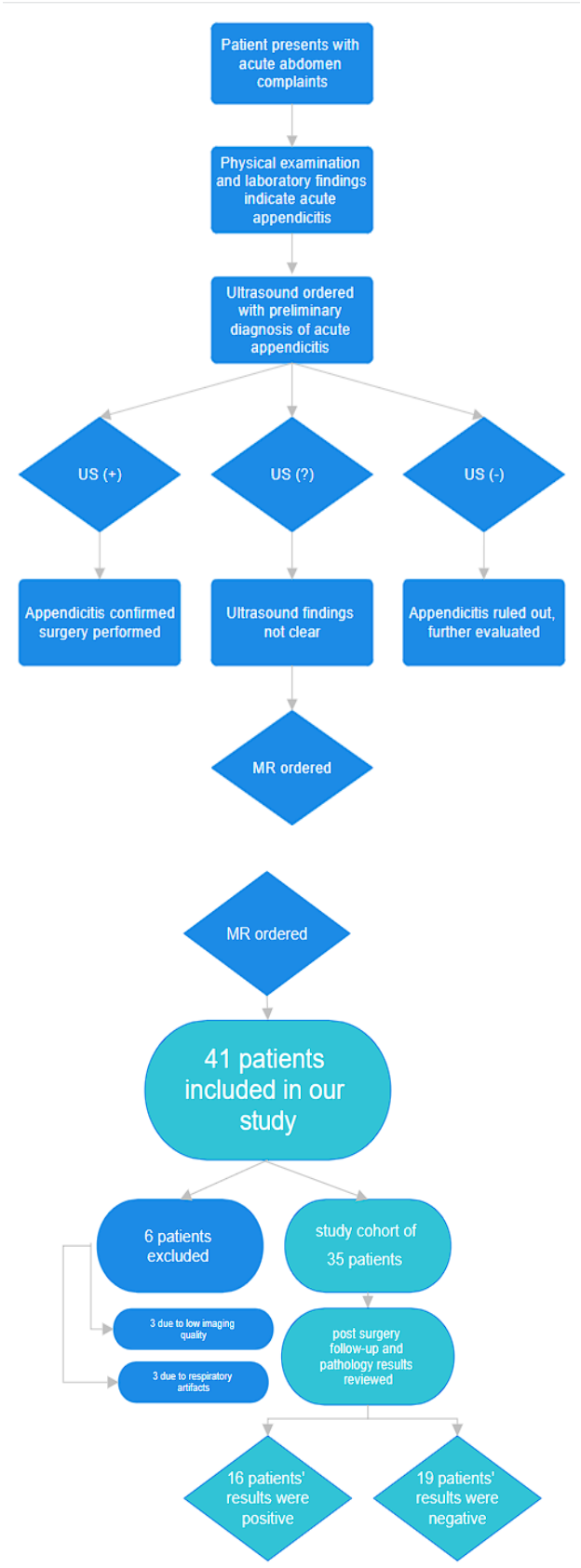

Figure 1: Flowchart presenting the patient selection and processing for our study.

weighted imaging as well as diffusion-weighted imaging (DWI) at B-values of 200, 400, and 600 s/mm². The imaging covered the lower abdominal region. DWI images were acquired without breath-holding. An intensity increase in the restricted diffusion area was expected in images with a higher gradient strength. DWI parameters were set as follows: inversion time (IT) 2200 ms, echo time (TE) minimum, repetition time (TR) 10,000 ms, spacing 1.00, phase 160, field of view (FOV) 44, number of excitations (Nex) 4, slice thickness 10 mm, duration 3 minutes. The total duration of the MRI scan was 14 minutes. No respiratory artifacts were observed in the 35 patients that were selected for the study.

MRI Evaluation: The image processing was performed by workstation, and the reference sequence utilized to confirm the location of appendicitis was T2-weighted imaging. Two different radiologists, who had two and four years of experience and who were blinded to ultrasonography and pathology findings, evaluated the images retrospectively. All patients with a preliminary diagnosis of acute appendicitis completed the procedure. Two radiologists who were blinded to pathology and ultrasonography results evaluated the B200, B400, and B600 images regarding the likelihood of appendicitis using a 5-point Likert scale ranging from 1 to 5 (Table 1).

1	No probability for appendicitis
2	Low probability for appendicitis
3	Intermediate probability for appendicitis
4	High probability for appendicitis
5	Appendicitis

Table 1. Scoring system used for evaluating DWI images in our study.

These were the routine B-values at the hospital where the data was retrieved. The scoring system was a subjective method used by two physicians based on the severity of diffusion restriction of the appendix itself, without considering secondary findings of appendicitis such as peri-appendiceal inflammation or fluid; 1 meaning no diffusion restriction and 5 being the most severe. Scores of three or higher were considered positive for appendicitis on DWI images, and calculations were performed (Sensitivity, Specificity, Positive Predictive Value, Negative Predictive Value, Accuracy). Additionally, the patients were then assessed using ROC analysis.

The investigator radiologist gathered clinical data, ultrasonography findings, diffusion-weighted MRI images, surgical-pathology results, and clinical follow-up outcomes of the study patients retrospectively.

RESULTS

Our study comprised 35 patients who underwent diffusion-weighted MRI for suspected acute appendicitis. Out of the participants, 63% (22) were male, and 37% (13) were female. The age of the patients varied from 16 to 80 years, with the mean age being 34. All patients underwent a transabdominal ultrasound (USG) examination for suspected acute appendicitis. Out of the 41 patients initially considered for the study, six were excluded due to low-quality diffusion images and respiratory artifacts. Consequently, the study cohort comprises 35 individuals.

Nineteen patients in our study underwent surgery for appendicitis. Among the remaining 16 patients, clinical symptoms improved during clinical follow-up, and one patient was diagnosed with nephrolithiasis based on laboratory findings.

The sensitivity, specificity, positive predictive value, and negative predictive values for B200, B400, and B600 diffusion-weighted images were calculated for two different evaluating radiologists and are presented (Table 2).

All 19 appendicitis patients in our study were diagnosed as positive on ultrasonography. However, among the three non-appendicitis patients, ultrasonography indicated appendicitis. In contrast, all of these patients were evaluated as non-appendicitis cases by one of our radiologists on diffusion-weighted images, while the other radiologist interpreted only one patient as non-appendicitis.

Sensitivity values for B200, B400, and B600 images were measured as 73.6%, 84%, and 89%, respectively, by the first radiologist, and 57%, 52%, and 63%, respectively, by the second radiologist (Table 2).

Magnetic resonance imaging (MRI) findings for selected patients are illustrated in Figures 1, 2, and 3.

	1st Radiologist B200	2nd Radiologist B200	1st Radiologist B400	2nd Radiologist B400	1st Radiologist B600	2nd Radiologist B600
Specificity	10/16 % 62.5	14/16 % 87,5	12/16 % 75	13/16 % 81,5	8/16 % 50	12/16 % 75
Sensitivity	14/19 % 73,6	11/19 % 57	16/19 % 84	10/19 % 52	17/19 % 89	12/19 % 63
Positive predictive value	10/15 % 66	14/22 % 63	12/15 % 80	13/22 % 59	8/10 % 80	12/19 % 63
Negative predictive value	14/20 % 70	11/13 % 84	16/20 % 80	10/13 % 76	17/25 % 68	12/16 % 75
Accuracy	24/35 % 68	25/35 % 71	28/35 % 80	23/35 % 65	25/35 % 71	24/35 % 68

Table 2. Comparison of sensitivity, specificity, positive and negative predictive value and accuracy values of B200, B400 and B600 DWI in terms of the 1st and 2nd radiologists

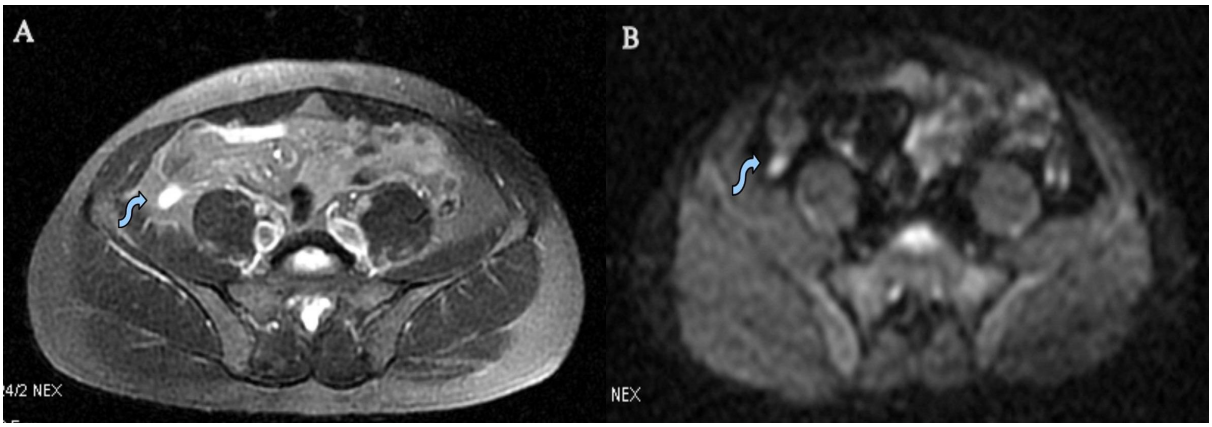

Figure 2: One of our patients, a 16-year-old male who had a pre-diagnosis of acute appendicitis underwent MRI. After surgery, the pathology report confirmed appendicitis. A. T2-weighted image revealing increased wall thickness of the appendix (curved arrow) and peri-appendiceal free fluid. B. Diffusion-weighted image displaying diffusion restriction in the appendix wall (curved arrow).

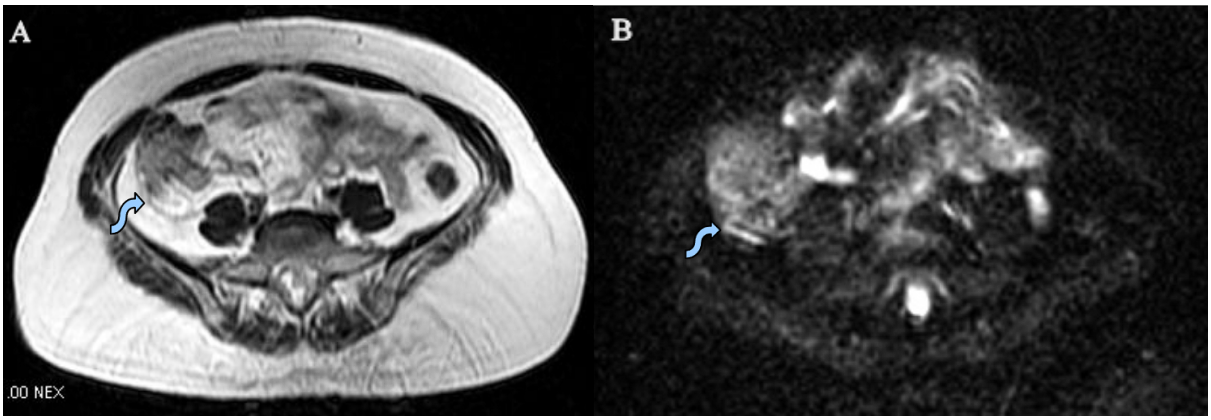

Figure 3: One of our patients, a 41-year-old female patient who had a pre-diagnosis of acute appendicitis underwent MRI. The patient underwent surgery on the same day, and the pathology report confirmed appendicitis. A. In the T2-weighted image, there is an increase in wall thickness of the appendix (curved arrow). B. In the diffusion-weighted image, diffusion restriction is observed in the appendix wall (curved arrow).

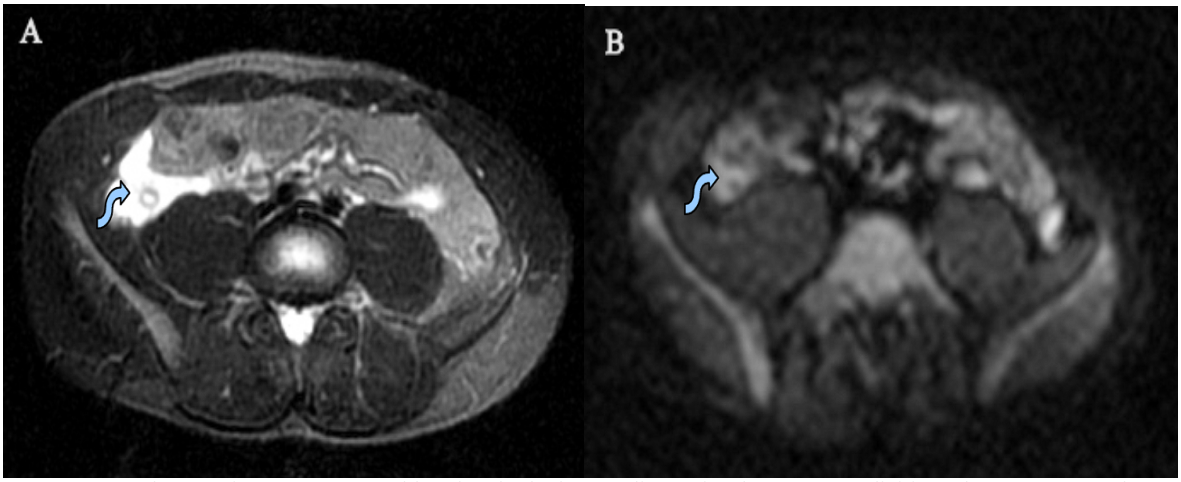

Figure 4: One of our patients, a 32-year-old male who had a pre-diagnosis of acute appendicitis underwent MRI. After surgery, the pathology report confirmed appendicitis. A. In the T2-weighted image, there is increased signal intensity in the appendix and surrounding area (curved arrow). B. In the diffusion-weighted image, there is significant diffusion restriction in the appendix wall (curved arrow)

DISCUSSION

In recent studies, ultrasound has emerged as the favored imaging modality for adult patients undergoing evaluation for suspected appendicitis. CT is suggested for cases where the diagnosis remains uncertain following an ultrasound evaluation[5]. The usage of CT in suspected appendicitis cases, in addition to ultrasound, has significantly reduced the likelihood of negative appendectomy without negatively impacting hospital stay and perforation rates. However, the noteworthy downside of CT is the significant exposure of radiation to the patient, which is particularly concerning for children, young patients, and pregnant individuals[6]. MR imaging has demonstrated favorable outcomes in the detection and exclusion of appendicitis [6-12].

In a recently conducted study, Bijnen et al. emphasized a remarkable association between the extraction of a healthy appendix and increased expenses and complications. To curtail costs, exploring the utilization of supplementary diagnostic tools ought to be taken into account. Diagnostic laparoscopy, an expensive diagnostic method, must preferably be reserved for selected patients to prevent further escalation of costs [13].

MR imaging is not a commonly employed modality when it comes to acute appendicitis diagnosis. It has been reported to be valuable in assessing local inflammation in cases of acute abdomen[14]. MRI features Short Tau Inversion Recovery (STIR) sequences that are particularly sensitive to fluid collections, providing rapid imaging with good resolution at a slice thickness of 2-4 mm[15-17]. Fast T2-weighted and T1-weighted images are useful for tissue visualization. However, findings such as thickened bowel walls, local inflammatory signs, and fluid collections located in the lower right quadrant might indicate conditions other than acute appendicitis. A meta-analysis evaluated a comparison among the diagnostic accuracy of MRI, CT, and US examinations among pediatric patients showing clinical suspicion of acute appendicitis. As a result, MRI showed a slight advantage over US as well as CT, though the difference did not result in being statistically meaningful [17].

In a meta-analysis conducted by Barger et al., MRI was reported to have a sensitivity of 92-99% and a specificity of 94-99%[18]. These rates are almost comparable to those of CT imaging. MRI has been reported as a viable alternative to CT scans for secondary imaging in the diagnosis of acute appendicitis in children[19]. However, interpreting MR images requires experience. The primary reason for the difference in interpretations in our study may be the varying levels of experience with DW-MRI in diagnosing appendicitis. Consequently, the use of MRI for the diagnosis of acute appendicitis appears to be limited to pregnant women and children[20]. With the increased use of DW-MRI in acute appendicitis, the differences in interpretation among doctors may decrease, leading to a broader clinical application.

There are multiple limitations to the use of MR in acute appendicitis. These include high costs and the requirement for a 24-hour operating MRI system. Though there are disadvantages like this, advancements in MRI technology over the recent years, along with an increasing number of MRI devices, are likely to reduce these challenges. Moreover, ensuring patient comfort during MRI examinations can be challenging. In our study, a safe, comfortable, and rapid investigation was provided to patients with pain using an MRI protocol without oral or intravenous contrast administration. None of the patients pre-diagnosed with appendicitis left the procedure incomplete.

One noteworthy limitation of our study is that we chose a reference slice thickness of 10 mm for

diffusion-weighted images. This choice substantially reduced the sensitivity and specificity of diffusion-weighted images. In addition, the B-values that were chosen were routinely used in the hospital where the data was taken. At low b-values, DWI (Diffusion-Weighted Imaging) is more similar to a T2-weighted image. Therefore, the absence of T2 images did not pose a problem in our study. However, we encountered issues due to the low spatial resolution, low signal-to-noise ratio (SNR), and motion-related artifacts (such as respiration, arterial pulsations, and bowel movements) in diffusion images. The scans were generated within a timeframe of 30-60 milliseconds. Consequently, most of the issues related to motion artifacts were eliminated. The low spatial resolution issues of DWI, particularly at high b-values (e.g., 1000 s/mm²), restrict the appearance of anatomical details in most images when SNR decreases. Therefore, we utilized low b-value (200-400-600 s/mm²) images due to the similarity of DWI images to T2 images, which aided in visualizing anatomical details.

Furthermore, one of the most critical issues in appendicitis diagnosis is the presence of various differential diagnoses causing right lower quadrant pain, including diverticulitis, Crohn's disease, and mesenteric lymphadenitis. These conditions can lead to secondary findings of appendicitis, such as peri-appendiceal inflammation and fluid collection. We posit that diffusion MRI's ability to demonstrate ischemia at the cellular level in the appendix will be valuable in differentiating these pathologies. As diffusion MRI is a rapid imaging technique and with further improvement of MRI technology to correct observed artifacts, we anticipate an increase in its utility for excluding other pathologies. We believe that the usage of MRI in appendicitis will increase, potentially surpassing CT, especially in selected cases, due to the absence of radiation dose concerns, with the advancement of MRI technology, reduced artifacts, and improved resolution.

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