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Diffusion-weighted imaging versus non-contrast magnetic resonance imaging in the diagnosis of acute appendicitis during pregnancy

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SUMMARY

OBJECTIVE: The aim of this study was to evaluate the diagnostic performance of diffusion-weighted imaging compared to non-contrast magnetic resonance imaging in the differential diagnosis of acute appendicitis in pregnant patients.

METHODS: A total of 72 pregnant patients with the suspicion of acute appendicitis who underwent magnetic resonance imaging combined with diffusion-weighted imaging examinations were enrolled in this retrospective study. Magnetic resonance imaging images (non-contrast and diffusion-weighted imaging sequences) were evaluated. Moreover, apparent diffusion coefficient ratios were estimated. The diagnostic performances of magnetic resonance imaging and diffusion-weighted imaging findings were statistically analyzed on the basis of surgical and follow-up results.

RESULTS: Of 72 pregnant patients, 10 (14%) had acute appendicitis on magnetic resonance imaging and diffusion-weighted imaging. Among 10 patients with acute appendicitis, three (3/10) had perforation. diffusion-weighted imaging findings had higher sensitivity (90 versus 60%), negative predictive value (98.41 versus 93.94%), and accuracy (98.61 versus 94.44%) ratios compared to non-contrast magnetic resonance imaging in the diagnosis of acute appendicitis. There was one false-negative result on diffusion-weighted imaging. Diffusion restriction facilitated the detection of appendicitis. The apparent diffusion coefficient ratios were lower in acute appendicitis than in the normal appendix (0.70±0.19 versus 0.96±0.16) ($p<0.05$).

CONCLUSION: With a shorter scan time and higher diagnostic accuracy, diffusion-weighted imaging can be useful for the early diagnosis of acute appendicitis and for planning appropriate management.

KEYWORDS: Abdomen, Acute. Appendicitis. Diffusion. Magnetic resonance imaging. Pregnant Women.

INTRODUCTION

Acute appendicitis during pregnancy is a life-threatening emergency for both the mother and the fetus. Because of pregnancy-related anatomical and physiological changes, the differential diagnosis of acute appendicitis is frequently difficult. The clinical findings can mimic other diseases that present abdominal pain. It is important to decide whether surgical management is required or not. An accurate diagnosis is necessary for early management in pregnant patients with acute abdominal pain because of maternal and fetal mortality risks[1-7].

Ultrasonography (US) is the first choice of medical imaging modality for pregnant patients[2-5]. Due to maternal anatomical changes, bowel gas, and larger patient body habitus, US examination may be insufficient for accurate diagnosis. Computed tomography (CT) is avoided in pregnant patients due to radiation risk and teratogenic and carcinogenic effects on the fetus. Alternatively, magnetic resonance imaging (MRI) is performed in conflicting situations. Several studies have reported that MRI is a problem-solving modality in pregnant patients with acute abdomen pain[1-11]. Because of gadolinium accumulation in the amniotic fluid, non-contrast sequences should be considered[10]. Diffusion-weighted imaging (DWI) needs no contrast administration and has a short scan time (approximately 2 min). DWI depicts the randomized motion of water. Hypercellular tumors, ischemia, abscess, and hemorrhage show diffusion restriction. Diffusion restriction is measured on apparent diffusion coefficient (ADC) map[12,13].

MRI may have some heating effects on the fetus due to radiofrequency pulse, especially at longer scanning time[14-18]. Optimal imaging with shorter scan times is essential in pregnant patients, especially in emergent situations. Thus, we aimed to evaluate the diagnostic performance of DWI compared to non-contrast MRI in the differential diagnosis of acute appendicitis in pregnant patients.

METHODS

Study design and setting

This is a retrospective, analytic, and cross-sectional study. The Institutional Review Board approved this retrospective

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study, and informed consent was waived. Between January 2016 and January 2019, at a single institution, MRI examinations of 78 pregnant patients with the suspicion of acute appendicitis who had in-conclusive US examinations were reviewed from the picture archiving and communications system. Pregnant patients without follow-up or histopathological results (n=4) and patients without DWI sequences (n=2) were excluded. A total of 72 pregnant patients with the suspicion of acute appendicitis who had undergone abdominal MRI combined with DWI examinations were enrolled in this retrospective study. The mean age of pregnant patients was 29±6 (SD) years (range 18–42 years).

Magnetic resonance imaging protocol

All MRI examinations were performed on a 1.5-Tesla system (Optima MR450w, GE Healthcare, Milwaukee, WI, USA). Parameters of lower abdominal MRI sequences were sagittal T2-weighted periodically rotated overlapping parallel lines with enhanced reconstruction (PROPELLER) [TR/TE: 643/90 ms, the field of view (FOV): 330 mm, image matrix: 256×256, slice thickness 5 mm], coronal fat saturated T2-weighted PROPELLER (TR/TE: 5,023/71 ms, FOV: 400 mm, image matrix: 256×256, slice thickness: 5 mm), axial T2-weighted fast relaxation fast spin echo (FR-FSE) (TR/TE: 7,773/110 ms, FOV: 430 mm, image matrix: 256×192, slice thickness 5 mm), non-contrast axial T1 spin echo (TR/TE: 744/35 ms, FOV: 430 mm, image matrix: 256×192, slice thickness 5 mm), non-contrast axial T1 3D LAVA (TR/TE: 6.6/2.1 ms, FOV: 430 mm, image matrix: 256×192, slice thickness 5 mm) sequences, and axial diffusion-weighted single-shot echo-planar imaging (TR/TE: 7,098/35 ms, NEX: 4, FOV: 430, slice thickness: 5 mm) with b values 0 and 1,000 s/mm^2.

Image evaluation

MRI and DWI examinations of patients (n=72) were reviewed by an experienced radiologist who was blinded to the clinical data of patients. There were two sets for evaluation of MRI examinations; set 1 included non-contrast conventional MRI examinations without DWI, and set 2 included only DWI without conventional MRI sequences with the calculation of ADC values. Radiological findings were divided into two groups: only non-contrast MRI and only DWI findings. The characteristics of the appendix (normal/non-visualized/appendicitis, wall thickness, and diameter), intra-abdominal free fluid, pericecal fat stranding, lymph nodes, and other abnormalities were noted. Qualitative and quantitative DWI findings were investigated.

Region of interest (ROI) measurements were performed at the appendix and paravertebral muscle in the dedicated workstation. The mean ADC value was obtained for each visible normal appendix, normal paravertebral muscle, and appendicitis. Besides, the ADC ratio (the ratio of mean ADC of normal appendix/appendicitis to mean ADC of normal paravertebral muscle) was calculated for standardization.

After two sets of image interpretation, surgical and follow-up results were noted from the hospital information system. Patients were categorized into two groups: those with and those without acute appendicitis. MRI and DWI findings were analyzed according to surgical and follow-up results. The diagnostic accuracy of MRI and DWI for acute appendicitis was estimated. Specific MRI and DWI findings were investigated.

Statistical analysis

The distribution of parameters was analyzed by the Shapiro-Wilk test. Fisher's exact test or Mann-Whitney U test was used, where appropriate, and $p<0.05$ was used to determine statistical significance. Statistical analysis was done using the MedCalc 12.1.4.0 statistical software.

RESULTS

Of 72 pregnant patients, 10 (14%) had acute appendicitis on MRI plus DWI, and 29 (40%) had normal radiological findings. The mean gestational week was 24±9 (SD). The mean follow-up period of patients was 5.7±1.7 (SD) months.

There were 10 patients (14%) with acute appendicitis. Three patients with acute appendicitis (3/10, 30%) had perforation and abscess formation (Figure 1). Acute interventional management was performed on ten patients with acute appendicitis and one with ovarian torsion. The remaining patients (n=61) were conservatively treated and underwent follow-up. Among conservatively treated patients, no surgical management was needed until the parturition. Among patients with acute appendicitis, there was one false negativity on DWI and four false negativities in the non-contrast MRI group. For diagnosis of acute appendicitis, the sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and accuracy ratios of non-contrast MRI were 60% (26.24–87.84), 100% (94.22–100), 100%, 93.94% (87.89–97.07), and 94.44% (86.38–98.47), respectively. Only DWI had a sensitivity of 90% (55.50–99.75), specificity of 100% (94.22–100), PPV of 100%, NPV of 98.41% (90.62–99.75), and accuracy of 98.61% (92.50–99.96). In only DWI group, higher sensitivity, negative predictive value (NPV), and accuracy ratios were obtained for the diagnosis of acute appendicitis.

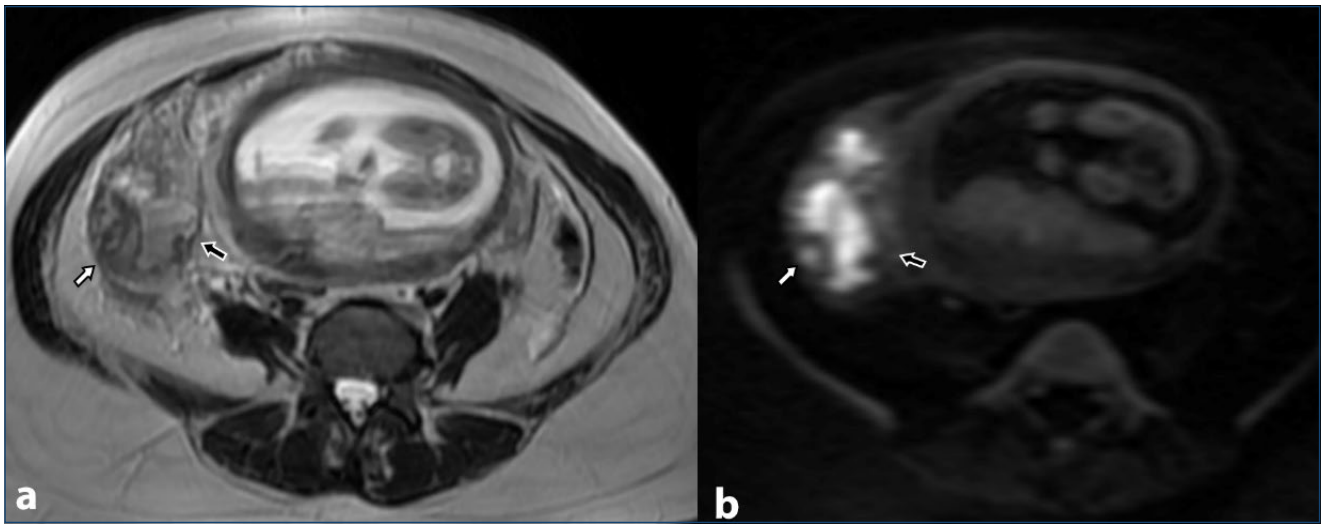

Figure 1. A 23-year-old pregnant patient in 21st week of gestation. Perforated appendicitis (white arrow) with free fluid, fat stranding, and abscess formation (black arrow) as shown on axial T2-weighted sequence (a) and on diffusion-weighted imaging (b).

Among 72 patients, seven had non-complicated acute appendicitis, three had perforated appendicitis associated with abscess, and 62 were without appendicitis.

In those patients without appendicitis, the normal appendix was shown on MRI in 33(33/62, 53%) and DWI in 14 (14/62, 22%). Non-contrast MRI sequences are more effective in the demonstration of a normal appendix. In the remaining patients, diagnosis of acute appendicitis was excluded due to non-visualization of the appendix and lack of indirect signs of acute appendicitis on MRI and DWI. Although lower mean age (27±6 versus 29±6 years old) and lower gestational week (22±8 versus 23±75 weeks) were observed in patients with acute appendicitis than those without appendicitis, there was no statistically significant difference between the two groups ($p>0.05$).

In our study, specific findings for acute appendicitis were a thick wall, increased diameter with a mean value of 9.6±2 mm (range: 8–14 mm), and pericecal fat stranding (Figure 2). Pericecal fat stranding, pericecal lymph nodes, and intra-abdominal free fluid were important clues for acute appendicitis (Table 1). Peripheral diffusion restriction was remarkable (Figure 3). Mean ADC values and ratios were significantly lower in acute appendicitis than in normal appendix ($0.99±0.29×10^{-3}$ mm^2/s and 0.70±0.19 versus $1.45±0.30×10^{-3}$ mm^2/s and 0.96±0.16) ($p<0.05$). However, anatomical details were more demonstrative on non-contrast MRI, especially on T2-weighted sequences.

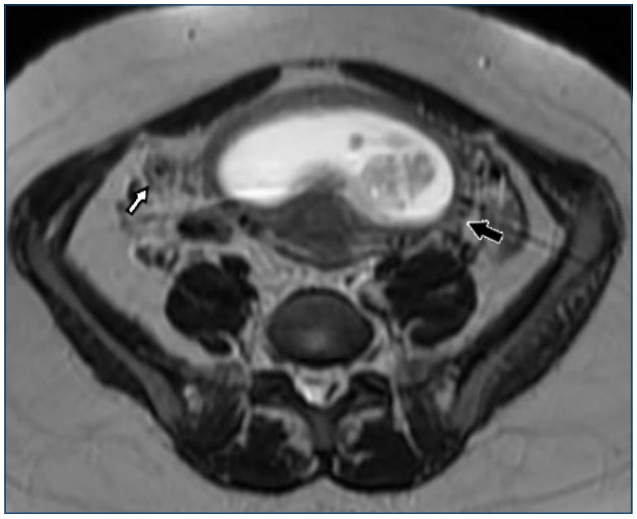

Figure 2. A 24-year-old pregnant patient in 16th week of gestation. Acute appendicitis (white arrow) with pericecal fat stranding and fetus (black arrow) are seen on axial T2-weighted sequence.

DISCUSSION

In pregnant patients with acute abdomen pain, acute appendicitis is the most common surgery-required etiology[19]. It is mostly seen in the second trimester[20]. MRI is usually performed following an inconclusive US examination. Administration of contrast agent is avoided because of transplacental passage. Sometimes, non-contrast MRI findings can be suspicious, and additional modalities can be required for accurate diagnosis. DWI has the advantages of short scanning time and no need for contrast agent[12,13].

Several studies have been conducted on the feasibility of MRI for acute appendicitis in pregnant patients. In a meta-analysis, MRI showed various sensitivity (range: 50–100%), specificity (range: 93–100%), PPV (range: 61–100%), and NPV (range: 94–100%) ratios for acute appendicitis in pregnant patients[5].

Table 1. The imaging findings of pregnant patients with acute appendicitis on magnetic resonance imaging and diffusion-weighted imaging.

Number of patients	Age	Gestational week	Diameter of appendix	Pericecal stranding*	Free fluid*	Abscess	Pericecal lymph nodes*	ADC ratio*
1	35	24	Perforated	+	+	+	+	0.40
2	24	16	8	+	-	-	+	0.85
3	27	19	Perforated	+	+	+	+	0.33
4	18	30	14	+	+	-	-	0.87
5	27	29	10	+	+	-	-	0.61
6	37	21	8	+	-	-	+	0.83
7	23	18	9	+	+	-	+	0.81
8	23	21	Perforated	+	+	+	+	0.78
9	27	31	8	+	+	-	-	0.81
10	30	6	10	+	+	-	-	0.75

*There was a statistically significant difference between patients with acute appendicitis and without appendicitis. In Fisher's exact test/Mann-Whitney U test, $p<0.05$ was used to determine statistical significance.

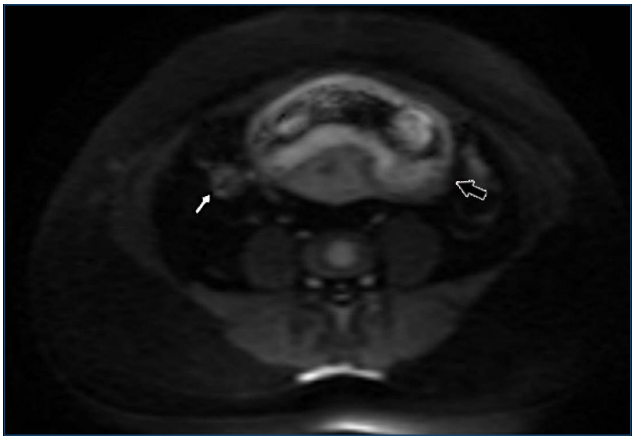

Figure 3. A 24-year-old pregnant patient in 16th week of gestation. Acute appendicitis (white arrow) with pericecal fat stranding and fetus (black arrow) are seen on diffusion-weighted imaging.

In another study, MRI showed high accuracy (88%) and specificity (92%) ratios with a sensitivity of 60% for acute appendicitis in pregnancy[17]. Tsai et al.[6] found high sensitivity (93%), specificity (95–96%), and accuracy (99.5%) ratios with one false negative (1/14) interpretation on MRI. They declared that peri-appendiceal fat stranding was an important clue. Non-visualization of the appendix and a lack of appendicitis signs can exclude acute appendicitis[6]. Similarly, none with non-visualized appendix had appendicitis in our study. Furthermore, the thick appendiceal wall and increased signal in pericecal fat were more noticeable in only DWI group with high accuracy ratios in our study.

In another study, Wi et al.[21] reported high sensitivity (100%), specificity (95%), and accuracy (96%) ratios of MRI in the diagnosis of acute appendicitis. Similar results were achieved by performing MRIs with and without DWI. They observed no significant difference in diagnostic performance with a combination of DWI[21]. Moreover, only DWI was not investigated for diagnosis of acute appendicitis.

Pedrosa et al.[18] documented that the negative laparoscopy rate was 30% in pregnant patients with suspicion of acute appendicitis. They found that the visualization of the normal appendix in patients without appendicitis was more prevalent in MRI compared to the US [87% (116/134) versus <2% (2/126)]. They recommended MRI to decrease negative laparoscopy rate[18].

In our study, we emphasized that DWI is an efficient modality for the early and accurate diagnosis of acute appendicitis in pregnant patients. Thick appendiceal wall, pericecal fat stranding, intraabdominal fluid, and peripheral diffusion restriction with a low ADC ratio were specific findings for acute appendicitis. Non-visualization of the appendix was helpful for the exclusion of appendicitis. With higher accuracy, DWI improves the notification of abnormality. Therefore, unnecessary laparoscopic procedures can be avoided.

There are some limitations to our study. First, retrospectively collected data were analyzed. Second, the sample size was small owing to the rarity of MRI with DWI examinations in pregnant patients with acute abdomen pain. Third, an experienced radiologist evaluated images into two sets. It can lead to a possible bias.

CONCLUSION

Early and accurate diagnosis of acute abdomen is important to decrease maternal and fetal mortality. In a pregnant patient with conflicting diagnosis, DWI can be useful with or without

non-contrast MRI for the diagnosis of appendicitis, with higher diagnostic accuracy and shorter scan time.

ETHICAL APPROVAL

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. This study was performed in line with the principles of the Declaration of Helsinki. Approval was granted by the Umraniye Training and Research Hospital Institutional Clinical Research Ethics Committee (Date: 23.01.2019/No: 234).

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