Emerg Radiol (2009) 16:133–141
DOI 10.1007/s10140-008-0748-8

ORIGINAL ARTICLE

Emergency MRI of acute pelvic pain: MR protocol with no oral contrast

Ajay K. Singh · Hemali Desai · Robert A. Novelline

Received: 30 March 2008 / Accepted: 24 June 2008 / Published online: 23 July 2008

Abstract The aim of this study was to evaluate the efficacy of magnetic resonance (MR) without oral contrast in the assessment of suspected acute pathologies of the pelvis in pregnant and non-pregnant patients. Sixty-seven patients who had MR of the lower abdomen and pelvis for acute abdomen were included in the study. The MR examinations were evaluated for indication of the study, type of MR sequences, and sensitivity of MR in diagnosing the disease. T2 single shot fast spin echo (SS-FSE), T2 FSE, short tau inversion recovery, pre-gadolinium T1, and post-gadolinium T1 sequences were utilized. There were 30 pregnant and two postpartum women in the study group. Positive pelvic MR findings were seen in 73% (49/67). Final diagnoses were acute appendicitis (n=12), ovarian torsion (n=6), abscess (n=3), tubo-ovarian abscess (n=2), ovarian tumor (n=2), degenerating fibroid (n=3), and perianal fistula (n=2). For acute appendicitis, sensitivity was 100% (12/12), and positive predictive value was 92% (12/13). Post-gadolinium T1-weighted sequences and T2 SS-FSE with FS were the sequences, which were most likely to best demonstrate the acute appendicitis. For ovarian torsion, the sensitivity was 86% (6/7), and positive predictive value was 100% (6/6). MR imaging is an efficacious means of diagnosing acute appendicitis, ovarian torsions, and other adnexal diseases in the acute setting. The four sequence protocol without oral contrast offers an excellent means of investigating the cause of acute lower abdominal and pelvic pain.

Keywords MR · Appendicitis · Acute abdomen · Ovarian torsion · Fibroid degeneration

A. K. Singh (✉)
Department of Radiology, Massachusetts General Hospital,
Boston, MA, USA
e-mail: mghpartners@yahoo.com

A. K. Singh
Department of Radiology,
University of Massachusetts Memorial Medical Center,
Worcester, MA, USA

H. Desai · R. A. Novelline
Division of Emergency Radiology, Department of Radiology,
Massachusetts General Hospital,
Boston, MA 02114, USA

Introduction

An acute abdominal condition is the most common cause of a patient's visit to the emergency department. Acute abdominal and pelvic pain present a diagnostic challenge in the emergency department as 53% of all non-trauma interventions are performed in the acute care setting; hence, rapid triage is crucial for subsequent management [1]. Ultrasound (US) and computed tomography (CT) are the front line technologies in the early imaging diagnosis of patients with acute abdomen. In general, MR has not been a frontline test in the assessment of an acute abdomen.

There are limited publications on the utilization of MR in the acute abdomen and pelvic pathologies. Some of the studies advocate the use of oral contrast, thereby adding 1 to 1.5 h of time before which an MR can be obtained [1]. In this investigation, we aim to evaluate the role of MRI in the diagnosis of acute pelvic pathologies in pregnant and non-pregnant patients, using dedicated sequences without the use of oral contrast.

Materials and methods

The study was conducted in compliance with HIPAA and was approved by the institutional review board. We searched the radiology database at University of Massachusetts

Fig. 1 Acute appendicitis. Post-gadolinium T1-weighted axial image demonstrates 11-mm diameter appendix with intense appendiceal wall enhancement (*curved arrow*). A right adenexal cyst is also identified

Memorial Medical Center and Massachusetts General Hospital for patients who were evaluated with MRI of the pelvis performed on patients presenting with acute lower abdominal and pelvic pain from 2001 to 2007.

All patients who had MR for oncology indications, magnetic resonance cholangiopancreatography, and MR angiograms were excluded from the study.

MR protocol

The MR exams were performed on a 1.5 Tesla MR scanner (Excite Twinspeed, GE Medical systems, Waukesha, WI, USA). The imaging protocol for the evaluation of acute appendicitis included triplanar fat saturated T2 single shot fast spin echo (SS-FSE), axial T2 fast spin echo (FSE), axial short tau inversion recovery (STIR), axial pre-contrast, and axial post-contrast T1-weighted fat saturated sequences, except in pregnant patients where post-gadolinium sequences were not obtained. Axial T2-FSE sequences were obtained without fat saturation and, if required, with fat saturation. In patients where acute appendicitis was not in the differential diagnosis, axial STIR sequence was optional. A board-certified radiologist monitored the study as it was being performed and was able to modify plane of imaging when he deemed it necessary.

In pregnant patients with suspected appendicitis, the sequences obtained were triplanar fat saturated SS-FSE, axial T2 FSE, and axial STIR. At the discretion of the radiologist monitoring the study, the T2 FSE sequences were without and with FS. There were no non-contrast or post-contrast T1-weighted sequences obtained in pregnant patients.

A phased array body coil was used to take advantage of increased signal-to-noise ratio compared with that of the built-in body coil. No oral contrast agent was used for the study. Intravenous gadolinium (Magnevist-Berlex Laboratories. Wayne, NJ, USA) was used in the MR imaging except in pregnant patients. Intravenous gadolinium was administered at a dose of 0.1 mmol/kg and a rate of 2 ml/s followed by a saline flush.

When feasible, the MR sequences were performed during suspended respiration at the end of expiration. The field of view ranged from 28 to 38 in., depending on the patients body habitus. In general, the imaging was performed from L3 vertebra level to the pelvis, unless a gravid uterus was seen to displace the cecum in cranial direction. All studies for suspected appendicitis were monitored, with the imaged area modified based on the results of first SS FSE sequence.

Image interpretation

Two experienced radiologists (with 5 and 10 years experience) reviewed all MR scans of the abdomen and pelvis. The radiologists were not blinded to the clinical information. In case of lack of consensus between the two radiologists, a third radiologist (more than 20 years experience) was involved in the final MR interpretation. The images were available for interpretation on an Impax DS3000 SP4SU2 PACS workstation (AGFA Technical Imaging Systems) or IDX Imagecast system (IDX Systems, Burlington, VT, USA).

The MR examinations were evaluated for indication of the study, type of MR sequences, and sensitivity of MR in diagnosing the disease for which the MR examination was performed. Each MR scan was evaluated for the visualization of the appendix and cecum and the sequence, which best shows the inflamed appendix.

The medical records of all 67 patients were reviewed for indication of MRI, management (medical, surgical, or intervention), final diagnosis at discharge and pathologic findings in case of surgical management. The presence of a dilated appendix (>7 mm), thickened wall (>2 mm), periappendiceal inflammation, and wall enhancement more than the ileal loops were considered findings of acute appendicitis.

Fig. 2 Acute appendicitis. Axial STIR sequence demonstrates 9-mm diameter appendix with hyperintensity in the wall (*arrowhead*) and some high signal intensity periappendiceal inflammatory changes (*curved arrow*)

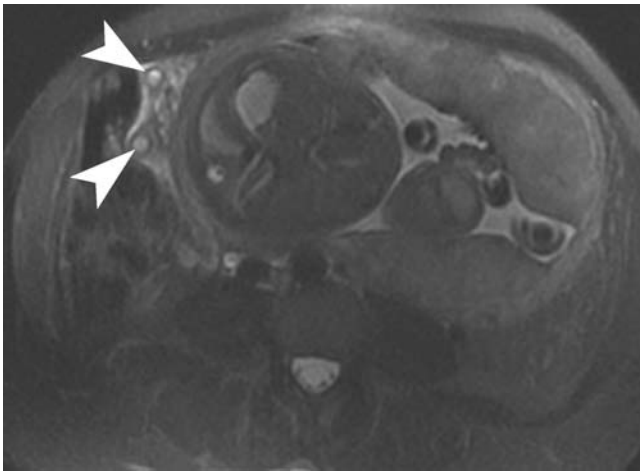

Fig. 3 Acute appendicitis. Axial T2 FSE sequence demonstrates fluid containing dilated appendiceal lumen (*arrowheads*) with periappendiceal fluid in a patient with term pregnancy

Results

Among the 67 patients (mean, 34 years; age range, 11–69 years) who had a pelvic MRI, 30 patients were pregnant and two were post-partum. The majority of the patients in this study were female (M/F=6:61).

Right lower quadrant pain with primary clinical suspicion of acute appendicitis was the presentation in 40 (60%) out of 67 cases and was the most common indication for pelvic MR. Suspected acute adnexal pathology was the primary differential diagnosis in 12 (18%) patients. Left lower quadrant pain and Crohn's disease were the indications in four (6%) and three (4%) patients, respectively.

MR imaging identified a cause for the acute pain in 49 (73%) out of 67 patients. The three most common diagnoses on pelvic MRI were acute appendicitis (n=13), ovarian torsion (n=7), and uterine fibroids (n=6; Figs. 1, 2, 3, 4, and 5). One MR interpreted as acute appendicitis was false positive because the surgical diagnosis was transmural cecal ischemia and MR interpretation based on the

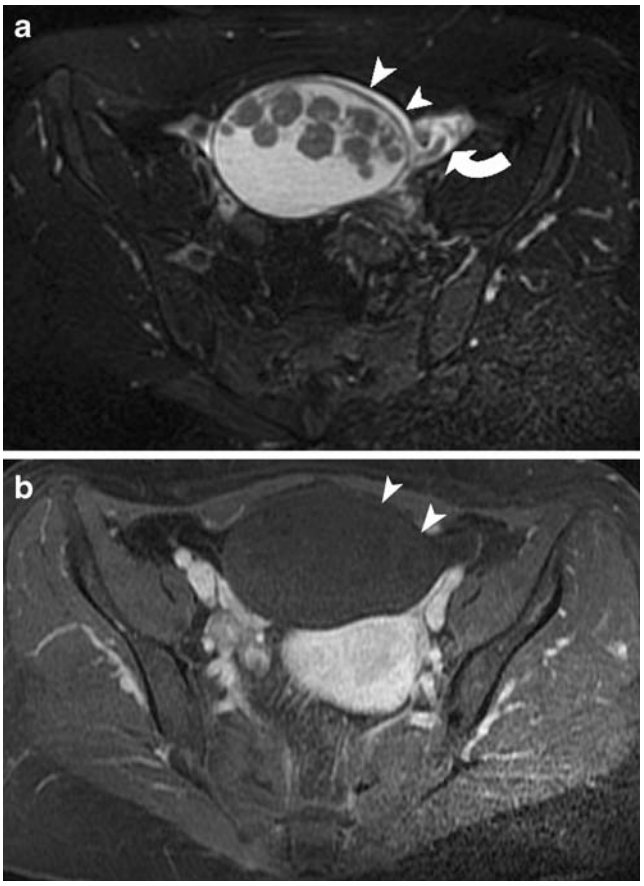

Fig. 4 Ovarian torsion. **a** Axial T2-weighted sequence shows high signal intensity edematous ovary (*arrowhead*) and an ovarian dermoid. The left fallopian tube (*curved arrow*) is thickened and twisted. **b** Axial post-gadolinium T1-weighted MR shows lack of enhancement of the ovarian parenchyma, indicating compromised blood flow

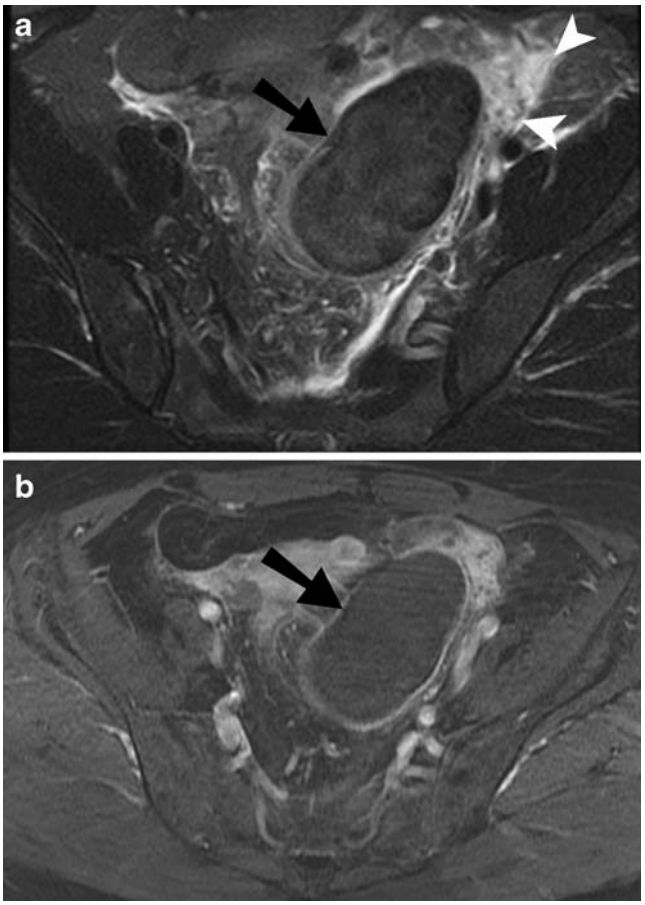

Fig. 5 Degenerating uterine fibroid. **a** Axial T2-FSE with fat saturation shows a uterine fibroid (*arrow*) with surrounding edema. **b** Axial post-gadolinium T1-weighted sequence shows lack of enhancement of the fibroid (*arrow*). At diagnostic laparoscopy, a degenerating fibroid was seen

Table 1 Final diagnosis in 49 out of the 67 patients with a positive diagnoses in the study

Final diagnosis	Number of patients
Acute appendicitis	12
Ovarian torsion	7
Uterine fibroid	6 (including 3 with degeneration)
Pelvic abscess	5 (2 with tubo-ovarian abscess)
Ovarian tumor	1
Perianal fistula	2
Retained products of conception	1
Acute colitis	1
Cecal ischemia	1
Vesicouretral junction calculus	1
Interstitial pregnancy	1
Enterocutaneous fistula	1
Endometrioma	1
Acute epiploic appendagitis	1
Pouchitis	1
Hematometra	1
Transient uterine contraction	1
Ovarian cyst	1
Right lower quadrant hematoma	1
Adynemic ileus	1
Infected urethral diverticulum	1
Ongoing abortion	1

inflammatory findings in the right lower quadrant. In two patients with heterotopic pregnancy and ovarian torsion, the MR scans were interpreted as ovarian neoplasm without torsion. The final diagnosis in the 49 patients is enumerated in Table 1 (Figs. 6, 7, 8, 9, 10, 11, 12, 13, and 14).

Pregnant population

There were 30 pregnant patients, 24 of whom underwent US prior to MR examination study. In the remaining patients, MR was requested by the ED physician, often because of the patient's body habitus and a wider differential diagnosis. There were 12 patients in first trimester, 13 in second trimester, and five in third trimester

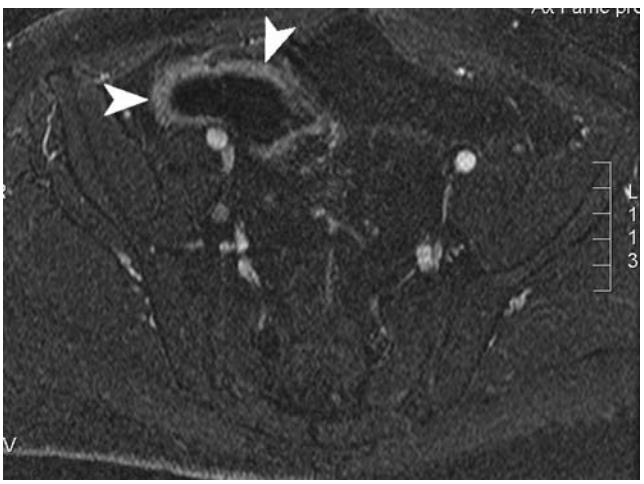

Fig. 6 Acute pouchitis. Axial post-gadolinium T1-weighted sequence demonstrates intense enhancement of the J pouch wall (*arrowheads*) in this patient with prior history of Crohn's disease

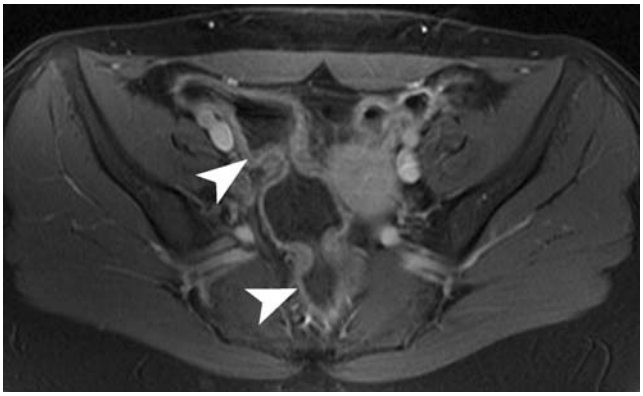

Fig. 7 Acute infectious colitis. Axial post-gadolinium T1-weighted sequence demonstrates intense enhancement of the sigmoid colonic wall with some wall thickening (*arrowheads*). The patient had pancolitis changes on rest of the MR

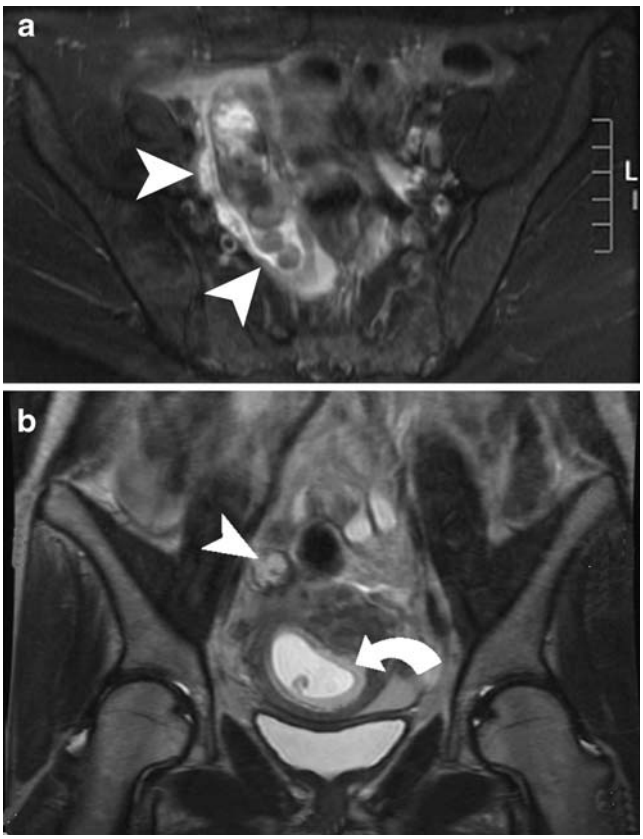

Fig. 8 Heterotopic pregnancy. **a** Axial FSE T2-weighted sequence shows a 9-cm diameter, oval-shaped right adnexal mass, corresponding to ectopic pregnancy (*arrowheads*). **b** Coronal T2 fast spin-echo sequence demonstrates the right adnexal ectopic pregnancy (*arrowhead*) in this patient presenting in first trimester of pregnancy. The gestational sac (*curved arrow*) is identified on the coronal image *curved arrow*

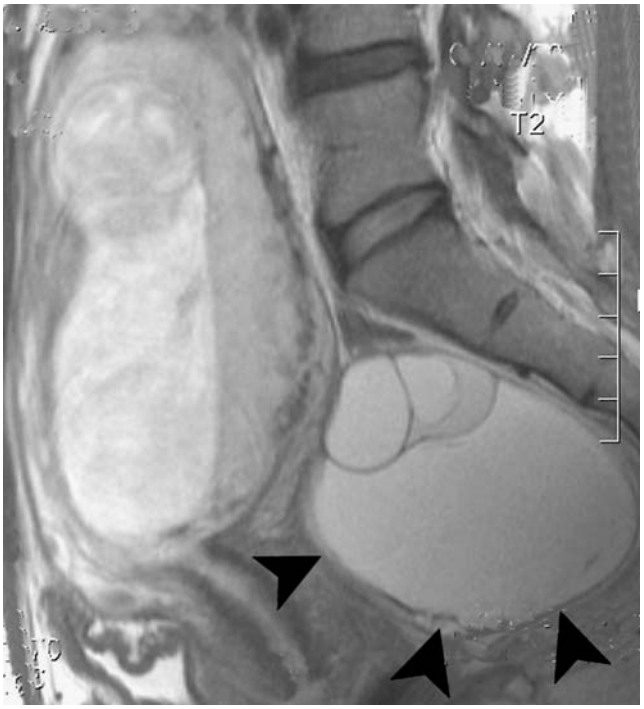

Fig. 9 Cystic ovarian neoplasm. Sagittal FSE T2-weighted sequence demonstrates a large presacral multiseptated cystic mass (*arrowheads*) in this patient in third trimester of pregnancy

of pregnancy. MR identified the cause of acute abdomen in 18 pregnant patients, enumerated in Table 2.

The location of the appendix and/or the base of cecum were in the right lower quadrant, below the level of the iliac crest in all 12 patients in first trimester. The location was above the level of iliac crest in ten out of 13 patients in the second trimester and in four out of five patients in the third trimester.

Appendicitis on MR

The appendix was visualized in 39 (69%) of the 56 pelvic MR cases where the location of the appendix was included in the field of view. These 39 cases also included all 12 cases of acute appendicitis in this study. In ten patients, the field of view did not include the location of appendix, while one patient had prior appendectomy.

In patients without acute appendicitis, the normal appendix was seen in only 61% (27/44) cases. The normal appendix was not seen on STIR sequence in any of the 44 patients. The combination of T2 FSE with FS, T2 SS-FSE with FS, STIR, and post-gadolinium T1-weighted sequences had a sensitivity and positive predictive value of 100% (12/12) and 92% (12/13), respectively, in the detection of acute appendicitis. The specificity and NPV of MR in detecting acute appendicitis was 96.4% (27/28) and 100% (27/27), respectively, in the 40 patients where acute appendicitis was a clinical consideration.

The apppendiceal caliber in proven cases of acute appendicitis ranged from 8 to 10 mm in 6 and 10 to 12 mm in six patients. The appendiceal wall was 3 mm or greater in thickness in nine out of 12 patients with appendicitis. The appendiceal wall showed enhancement greater than the ileal wall in all seven patients who had a contrast-enhanced MR for appendicitis. Periappendiceal fluid and inflammation were demonstrated in 12 and eight patients, respectively. Of the 12 patients, the findings of acute appendicitis was best demonstrated on Gadolinium-

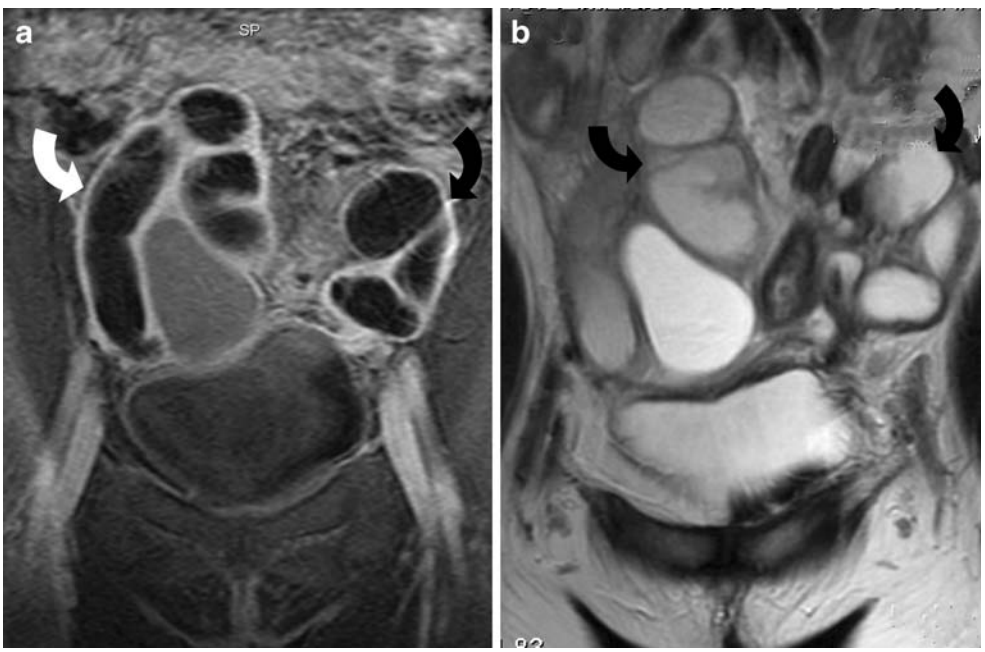

Fig. 10 Pyosalpinx. **a** Post-gadolinium T1-weighted sequence in coronal plane demonstrates tortuous tubular structures in bilateral pelvic adnexa with intense enhancement of the walls (*curved arrows*). **b** T2-weighted coronal fast spin-echo sequence also demonstrates tortuous tubular structures consistent with dilated fallopian tubes. The pear-shaped hyperintense cystic lesion located cranial to the urinary bladder represents an ovarian cyst

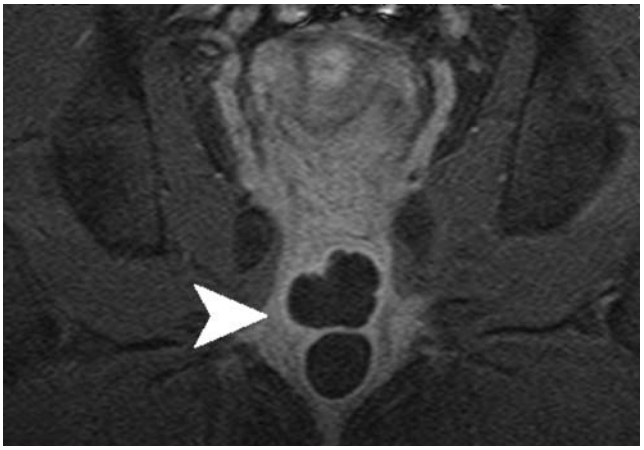

Fig. 11 Infected urethral diverticulum. Coronal post-contrast T1-weighted image demonstrates multilobulated ring-enhancing cystic lesion (*arrowhead*) located caudal to the neck of the urinary bladder

enhanced T1-weighted sequence in seven, SS-FSE in three, and STIR in one and equally well with STIR, T2-FSE, and SS-FSE in one patient. The findings of acute appendicitis were best appreciated on gadolinium-enhanced T1-weighted sequence in all seven patients where contrast enhancement was used for the MR.

Other pathologies

There were seven patients with ovarian torsion, six of whom demonstrated abnormal T2 high-signal intensity in the ovarian parenchyma and were correctly diagnosed as torsion (PPV, 86%). One case of torsion in a patient with cystadenofibroma was interpreted as no torsion and was the sole false negative case among ovarian torsion patients. The specificity and NPV was 100% (5/5) and 83.3% (5/6), respectively, in the 12 patients where ovarian torsion was suspected.

Four of the seven MR in the patients with proven ovarian torsion were non-contrast examinations. A post-contrast MR demonstrated failure of the ovarian parenchyma to enhance due to compromised vascular flow in two patients and a thickened ipsilateral fallopian tube in one patient. Four of the seven cases had an ovarian tumor, which likely predisposed to the torsion while one patient was postpartum. The ovarian tumors included two ovarian dermoids, one dysgerminoma, and one cystadenofibroma.

There were six uterine leiomyomas in the study, three of which showed features of degeneration. These features included abnormally T2 high-signal intensity in two and lack of enhancement in two cases of degenerating fibroid. Four of the six patients with fibroid were pregnant and were consequently imaged without contrast. All three degenerating fibroids were conservatively managed, one after laparoscopic confirmation.

Five patients had abscesses, two of which were tubo-ovarian abscesses. The diagnosis was based on ring enhancement of fluid collections.

Discussion

The American College of Radiology has recommended the use of MR over CT in pregnant patients with suspected acute appendicitis, when the US is non-diagnostic or equivocal. MR imaging offers the advantage of multiplanar imaging, excellent soft tissue contrast, no ionizing radiation, and an efficacy matching CT in majority of acute pathologies. It can be used to make a wide variety of diagnoses, including appendicitis, abscess, ovarian torsion, fibroid degeneration, hemorrhage, etc. [3–9].

Our study showed a high sensitivity and positive predictive value of 100% in the detection of acute

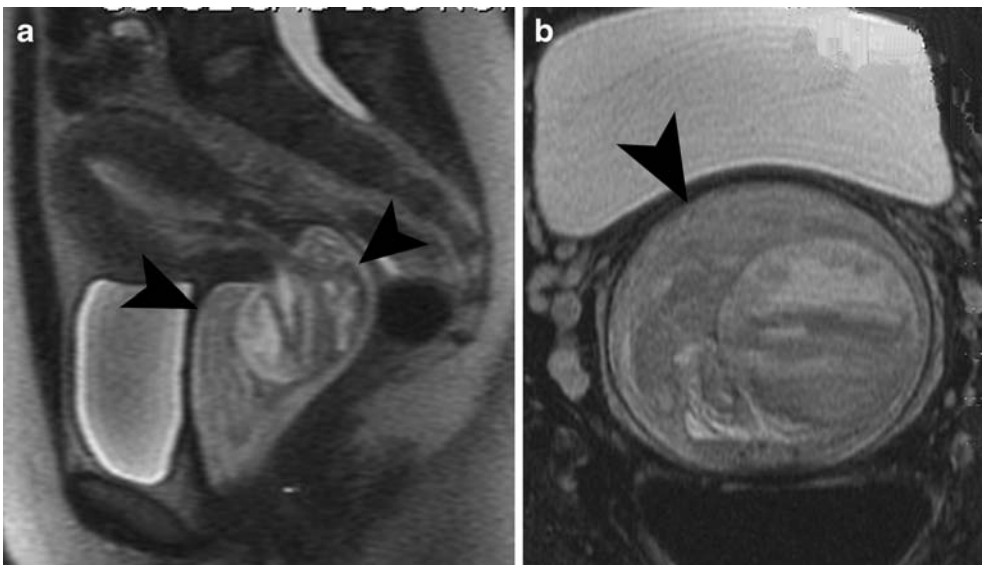

Fig. 12 Ongoing abortion. **a** Sagittal T2-weighted sequence demonstrates products of conception being extruded out into a dilated vagina (*arrowheads*). **b** Axial T2-weighted sequence also demonstrates distention of the vagina by products of conception (*arrowhead*)

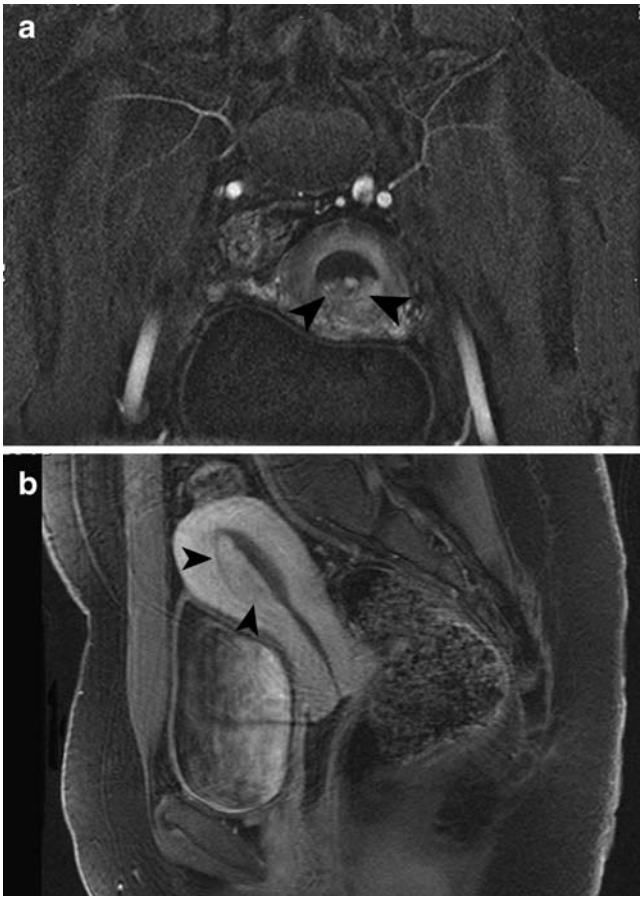

Fig. 13 Retained products of conception. Coronal (**a**) and sagittal (**b**) post-contrast T1-weighted images demonstrate heterogeneous signal intensity contents within the endometrial cavity (*arrowhead*) and most consistent with retained products of conception in this patient with vaginal bleeding

appendicitis and supports the utility of MRI in selected patients with acute pelvic pain and suspected appendicitis. Our results are in agreement with three previous studies on pregnant population [3–5].

Fig. 14 Endometrioma. Axial FSE T2-weighted sequence demonstrates a cystic lesion in the left adnexa with T2 shading (*curved arrow*) produced by products of hemorrhage

Table 2 Final diagnosis in the 18 out of 30 pregnant patients with a positive diagnosis

Final diagnosis	Number of patients
Acute appendicitis	4
Symptomatic uterine fibroids	4
Acute ovarian torsion	1
Ovarian tumor	1
Ectopic pregnancy	1
Ongoing abortion	1
Interstitial pregnancy	1
Constipation	1
Adynemic ileus	1
Braxton Hicks contraction	1
Ovarian cyst	1
Vesicouretral junction calculus	1

Unlike Pedrosa et al. [5] who gave negative oral contrast agent 1–1.5 h before the MR to eliminate susceptibility artifacts, we did not use oral contrast in any of our patient. Given our high sensitivity for the detection of acute appendicitis, the lack of oral contrast does not appear to effect the visualization of inflamed appendix. By not using oral contrast, we reduce the time between a physician's decision to request an MR and starting the actual MR scan. Moreover, it is also beneficial for the patient to be fasting if the patient needs to go for urgent surgery after the MR.

A normal appendix is seen as a blind-ending tubular structure hypointense on T1- and T2-weighted images in the right lower quadrant measuring up to 6 mm in diameter. Depending on the proportion of appendicitis in the study, the appendix can be visualized in 84% to 100% cases [3, 5, 6, 9]. In general, abnormal appendix is more likely to be seen than normal appendix. We visualized a normal appendix in 69% patients where the location of the appendix was included in the field of view. Although inflamed appendix could be seen in all cases, the visualization of normal appendix was only 61% on MR. This relatively lower rate of normal appendix visualization can be explained by the lack of oral contrast and the lack of nonfat saturated T1 sequence in our standard protocol for acute pain.

By restricting the number of sequences to SS-FSE, STIR, T2 FSE, and T1-weighted (pre- and post-gadolinium), we are able to keep the imaging time to less than 25 min. We do get pre- and post-gadolinium T1-weighted sequences with fat suppression only if the patient was not pregnant. In our experience, SS-FSE and post-gadolinium T1 with fat saturation are most likely to show a normal appendix. STIR sequence is least likely to demonstrate a normal appendix.

MR has been shown to have sensitivity comparable to CT in the detection of acute appendicitis. MRI has a reported sensitivity of 97%, specificity of 92%, negative predictive value of 96% and positive predictive value of 94% in the diagnosis of acute appendicitis [7]. We achieved

a comparable sensitivity of 100% in the detection of acute appendicitis in our study.

Other pelvic pathologies

Although appendicitis was the most common etiology of pelvic pain, MRI could also accurately diagnose other alternative causes of pelvic pain such as ovarian torsion, pelvic inflammatory disease, degenerating fibroid, and colitis, non-invasively.

Ovarian torsion is a well-known complication of ovarian tumors and cysts, which often act as a lead point. Approximately 10% to 20% of ovarian torsions occur in pregnant women. The MR imaging findings in ovarian torsion are ovarian enlargement caused by stromal edema, seen as diffuse high-signal intensity on T2-weighted images [11, 12]. Lack of enhancement of the septae in the mass indicates vascular compromise. Other MR features include tubal thickening, increased signal intensity (edema) within the tube on T2-weighted images, deviation of the uterus to the side of torsion, and a twisted pedicle [12–13]. Less common findings included hemorrhagic changes, which suggest hemorrhagic infarction [14]. In our study, we most commonly identified ovarian torsion (6/7) patients by the abnormally high T2-signal intensity of the ovarian parenchyma. The lack of ovarian enhancement and ipsilateral fallopian tube thickening were less common findings.

Uterine leiomyomas often enlarge during pregnancy and undergo symptomatic degeneration. MRI is an accurate imaging technique for detection, localization, and characterization of leiomyomas. Interstitial edema, the initial sign of degeneration, causes high signal intensity on T2-weighted images and shows enhancement on gadolinium-enhanced T1-weighted sequence [15]. On contrast MR imaging, cellular leiomyomas show contrast enhancement in the early phase, while degenerated leiomyomas show slight or irregular enhancement [16]. Leiomyomas with cystic degeneration show high-signal intensity on T2-weighted images, and the cystic areas do not enhance. There is high-signal intensity rim on T1-weighted images in degenerating leiomyomas and is likely secondary to the proteinaceous content of the blood or the T1-shortening effects of methemoglobin [17]. In our study, MRI detected six patients with uterine leiomyomas out of which three had had features of degeneration. The imaging features that helped support the diagnosis of degeneration in the leiomyoma was the presence of T2 hyperintensity and the lack of enhancement.

MR imaging can demonstrate the extent of pelvic inflammation as ill-defined hyperintense areas on fat-suppressed T2-weighted images with intense enhancement on contrast-enhanced fat-suppressed T1-weighted images. The sensitivity of MR imaging in the diagnosis of pelvic inflammatory disease is 95%, the specificity is 89%, and the accuracy is 93%. In our series, MR imaging features were suggestive of pelvic abscess in five patients, two of which were tubo-ovarian abscesses [18].

Limitations

The limitations of this study include the small study population and heterogeneous imaging protocol. The lack of T1-weighted non-fat saturated sequence, STIR, and post-gadolinium T1-weighted sequence is a limitation in drawing inference from the study. Although the study population had high rate of acute pathologies, they were heterogeneous, thereby limiting the usefulness with regards to a single acute pathology.

Conclusion

MR imaging is an efficacious means of diagnosing acute appendicitis and acute pelvic pathologies. The MR protocol using T2 SS-FSE, T2 FSE, STIR, and T1 sequences offers an efficacious means of investigating the cause of acute pain in pregnant and non-pregnant patients. Our study demonstrates high sensitivity in the detection of acute causes of acute pelvic pain, without the delay of oral contrast. Dedicated MRI in a selected group of patients can accurately diagnose or rule out acute appendicitis, ovarian torsion, and a wide spectrum of pelvic pathologies in pregnant and non-pregnant patients.

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