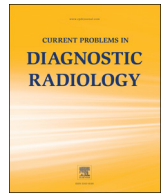




# Current Problems in Diagnostic Radiology

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## Challenges in Magnetic Resonance Imaging for Suspected Acute Appendicitis in Pregnant Patients

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The assessment of a gravid patient with abdominal pain is a clinical challenge, as one must consider not only the common etiologies for abdominal pain but also etiologies resulting from the pregnancy. Further complicating the assessment is the altered anatomy and physiology that result from the enlarged uterus displacing and compressing normal anatomical structures. This alteration of anatomy makes the symptoms of appendicitis more variable and thus the diagnosis more difficult. Appropriate and timely imaging can result in better patient outcomes, and when appendicitis is suspected, imaging investigation should not be delayed. This article reviews some of the challenges of magnetic resonance imaging in gravid patients with suspected appendicitis and presents strategies for imaging this population.

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### Introduction and Background

The assessment of a gravid patient with abdominal pain is a challenging endeavor. One must consider not only the common etiologies for abdominal pain but also etiologies resulting directly from the patients' gravid state.<sup>1</sup> Further complicating the assessment is the altered anatomy and physiology that result from the enlarged uterus displacing and compressing normal anatomical structures. As a pregnancy progresses and the uterus enlarges, it has been demonstrated that the appendix and cecum are gradually and progressively displaced superiorly.<sup>2</sup> This results in an altered clinical picture than would be characteristic for appendicitis and necessitates an imaging diagnosis.

Appendicitis in the gravid patient has the highest incidence in the second trimester.<sup>3</sup> Once appendicitis is complicated by perforation or abscess, there is an increased risk of fetal loss.<sup>4–6</sup> However, abdominal surgery during pregnancy also increases the risk of a poor outcome of pregnancy.<sup>6,7</sup> Thus, accurate and timely imaging diagnosis of appendicitis has greater importance in the gravid population.

When appendicitis is suspected, imaging investigation should not be delayed. In 2009, Pedrosa et al<sup>8</sup> demonstrated that magnetic resonance imaging (MRI) in the setting of suspected acute appendicitis results in a decreased rate of negative results on laparotomy and decreased risk of perforated appendicitis. Thus appropriate and timely imaging can result in better patient outcomes.

### If Appendicitis is Suspected in a Pregnant Patient, how Should I Proceed?

When recommending imaging in any clinical scenario, one should refer to the appropriateness criteria published by the American College of Radiology (ACR) (Table 1). The purpose of these criteria is to ensure that patients receive the most appropriate evidence-based care. In the setting of a gravid patient with suspected acute appendicitis, the first-line imaging modality is abdominal ultrasound, which garners an Appropriateness Criteria of 8, followed by MRI of the abdomen and pelvis *without contrast* with an appropriateness criteria of 7.<sup>9</sup> Ultrasound is an inexpensive test that should always precede MRI; however, it can be technically challenging in the setting of pregnancy. MRI should be considered in the gravid patient with equivocal ultrasound findings as it provides excellent anatomical detail and involves no ionizing radiation. The drawbacks of MRI are increased costs and decreased availability. computed tomography is faster, cheaper, and more available than MRI and has been validated in the pregnant population.<sup>10</sup> However, its use of ionizing radiation relegates it to an ACR appropriateness criteria of 6. A graphical representation of the imaging decision tree is summarized in Figure 1.

### Is MRI Safe in Pregnancy?

There are no long-term studies on the effect of in utero exposure to MRI. However, several short-term studies have identified no deleterious effects attributable to MRI.<sup>11–13</sup> In 2001, the ACR recognized the need for a guide to safe MRI practices and convened the first Blue Ribbon Panel on MR Safety. In the intervening years, the recommendations of this panel have twice

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**Table 1**  
Imaging recommendations for suspected appendicitis in pregnancy

Study	ACR recommendation
Ultrasound of abdomen	8
MRI abdomen and pelvis without contrast	7
Ultrasound of the pelvis	6
CT abdomen and pelvis with contrast	6
CT abdomen and pelvis without contrast	5
Abdominal radiograph	2
Barium enema	2
99mTc WBC scan abdomen and pelvis	2

CT, computed tomography; WBC, white blood cell. (Adapted from Rosen et al.<sup>9</sup>)

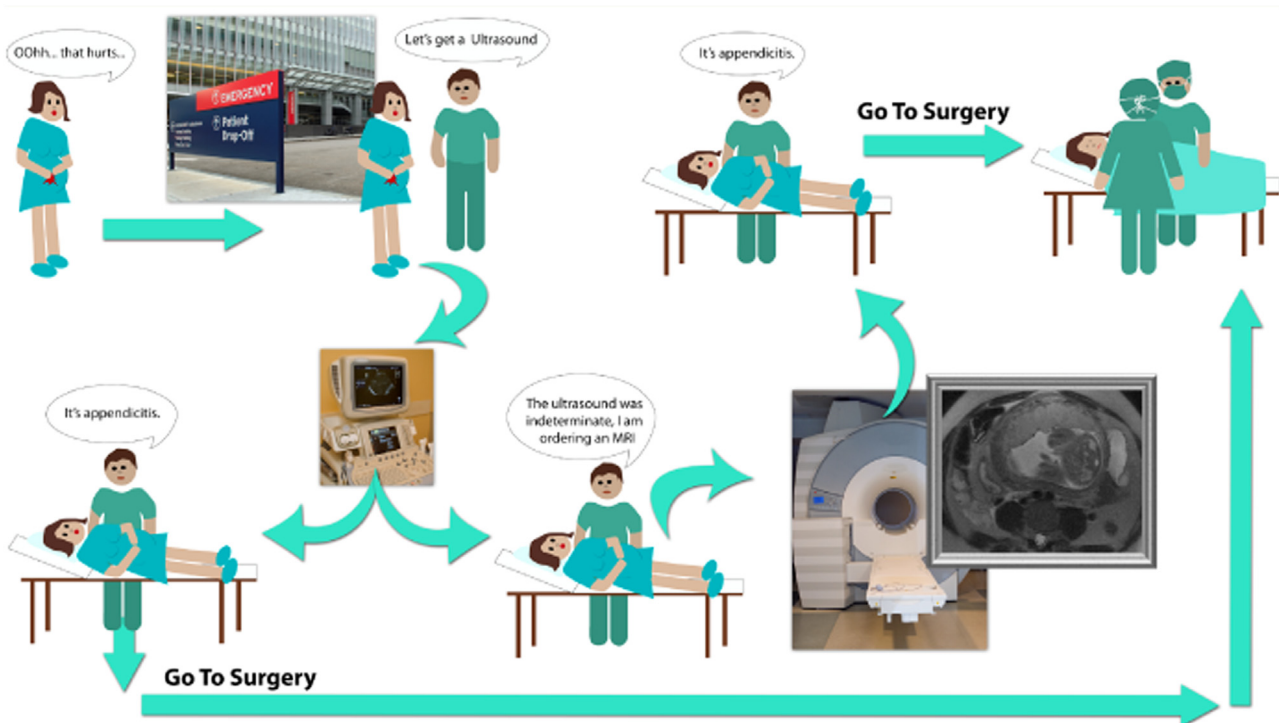
been revised, with the most recent iteration being published in 2013. The position of the Blue Ribbon Panel is that, although to date there is no conclusive evidence of any deleterious effects on the developing fetus, caution should nevertheless be exercised when utilizing MRI in the pregnant patient. MRI is presumed to be safe at any stage of pregnancy; however, examinations that can wait until the conclusion of pregnancy should be postponed.<sup>14</sup> If an examination cannot be postponed, then there should be a clear risk-benefit ratio warranting the study, and the radiologist must document the following:

1. The required information cannot be acquired with ultrasound.
2. The information being sought has the potential to alter the care of the fetus or the patient during the course of the pregnancy.
3. The information being sought is sufficiently important that “it would not be prudent” to delay its acquisition and cannot wait until the conclusion of the pregnancy.

Currently, the principle concern with MRI safety in pregnancy relates to the unknown effect of heating the fetal tissues that can ensue with deposition of radiofrequency energy.

**What Sequences Should I Perform and in What Order to Maximize Diagnostic Yield?**

At our institution, all MR examinations for appendicitis performed in the emergency department are performed under the direct supervision of a radiologist. We use an 8-channel surface coil and begin with the standard 3-plane localizer. We then perform 3-plane single-shot half-Fourier T2-weighted sequences with a large field of view encompassing the abdomen and pelvis. Although it is of limited resolution, they provide means of anatomically localizing the appendix and can be done without the radiologist present. Once the radiologist has reviewed the images to localize the cecum and the expected region of the appendix, the examination is localized to the pericecal region and a smaller field of view is employed. The technologist, without the radiologist present, can then complete the remainder of the standard sequences. Next, 3-plane single-shot half-Fourier T2-weighted sequences are again performed, this time with fat saturation to assess for periappendiceal inflammation. Single-shot half-Fourier T2-weighted sequences are performed at the beginning of the examination as they take only minutes to perform (usually less than 60 seconds per plane) and usually provide some diagnostic information if the patient is unable to tolerate the remainder of the sequences. We then perform an axial short tau inversion recovery (STIR) sequence and axial breath-hold T2 to better define appendiceal anatomy. Lastly, an axial T2-weighted fat-saturated sequence is performed to assess for subtler periappendiceal inflammatory change. The radiologist then returns to the scanner and reviews the images (with the patient on the table) to determine the need for additional imaging. As the MRI is performed with direct radiologist supervision, the protocol can be modified as needed, and under ideal circumstances, it requires approximately 20 minutes. The use of rectal saline is currently under investigation at Massachusetts General Hospital and has not yet been validated; however, in our experience, we have found it



**FIG 1.** Imaging algorithm for appendicitis in a gravid patient. A pregnant patient with right lower quadrant pain goes to the ER. The surgeon comes to see the patient and suspects appendicitis and orders an ultrasound. If the ultrasound is positive the patient goes for appendectomy. If the ultrasound is indeterminate then the next most appropriate imaging modality is MRI. ER, emergency room. (Color version of figure is available online.)

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