

# MRI Evaluation of Acute Abdominal Pain in the Pregnant Patient

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Acute abdominal pain in pregnant women poses a diagnostic challenge, as gastrointestinal, genitourinary, and gynecologic diseases may all manifest with nonspecific symptoms, which could lead to a delay in diagnosis. In the first portion of this review, we discuss the imaging approach to acute appendicitis in the pregnant patient with a brief overview of ultrasound (US) as the initial screening tool and MRI as the second-line tool. Computed tomography (CT) will also be discussed, although despite its superior resolution, it is not the preferred modality due to unknown carcinogenic risks of ionizing radiation to the fetus. As MRI is becoming increasingly available and used as a preferred imaging tool to evaluate the pregnant patient, the second portion of this review discusses MRI findings of myriad causes of abdominal pain during pregnancy.

## Imaging Evaluation of Acute Appendicitis

### *Graded Compression Ultrasound*

Graded compression US is the preferred initial imaging technique to evaluate for acute appendicitis in pregnant patients, since it is safe and readily available. Targeted imaging is performed from the right lower quad-

rant to the inferior liver edge for identification of the appendix, a tubular, blind-ending aperistaltic structure arising from the cecum. Imaging features compatible with acute appendicitis include a noncompressible appendix dilated > 6 mm in caliber. Variable anatomic location of the normal appendix, as well as variable displacement by the gravid uterus, can contribute to difficulty visualizing the appendix, leading to indeterminate exams. Several studies on the use of US for evaluation of acute appendicitis in pregnant women have yielded rates of indeterminate exams ranging from 88% to 96% cases,<sup>1-3</sup> with higher rates seen during the third trimester. Scanning patients in the left posterior oblique or lateral decubitus position may improve visualization of the appendix. In cases where the appendix is not visualized, US is of limited use in the assessment of alternative explanations for the patient's right lower quadrant pain, particularly in the evaluation of bowel pathology.

### *Computed Tomography*

The role of CT is well established in the evaluation of acute appendicitis. CT offers excellent anatomic detail, with 93% sensitivity and 96% specificity of unenhanced CT in the diagnosis of

acute appendicitis in the nonobstetric population.<sup>4</sup> In addition, CT is useful for the identification of alternative causes of right lower quadrant pain. However, CT should be used cautiously in obstetric patients due to the potential risks of radiation-induced carcinogenesis. Estimation of fetal radiation dose from an abdominopelvic CT is approximately 17 mGy. A dose of 50 mGy is considered the limit below which there is no harm from deterministic effects and the point at which the risk of stochastic effects is < 1%. However, there is an estimated doubling in the overall risk for childhood cancer in a fetus exposed to 30-50 mGy of radiation during MDCT appendix protocol examination.<sup>5</sup>

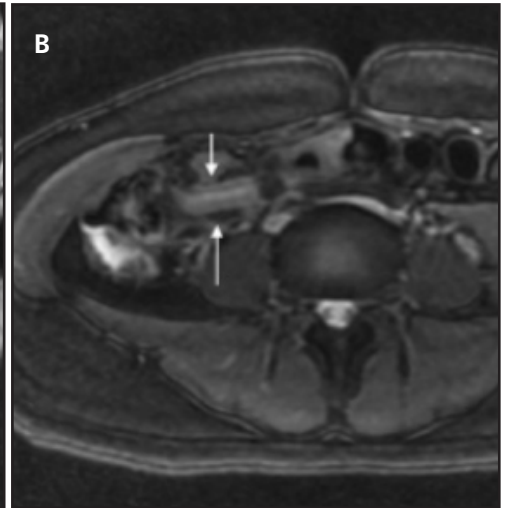
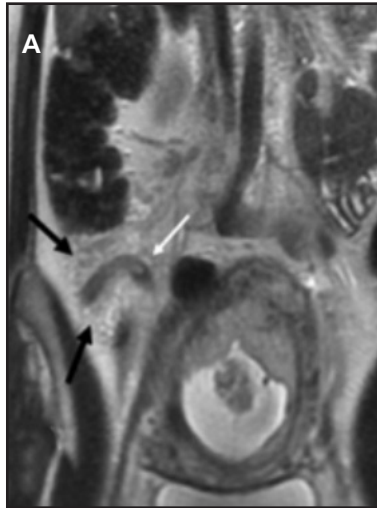
CT techniques can limit fetal radiation dose, including reducing the milliampere-seconds (mAs), increasing the pitch, and limiting the scan area, which may reduce the dose to as low as 3 mGy per examination.<sup>6</sup> However, these methods may result in suboptimal or even nondiagnostic imaging quality. Therefore, there is often a trade-off between radiation dosage and diagnostic quality.

### *MRI*

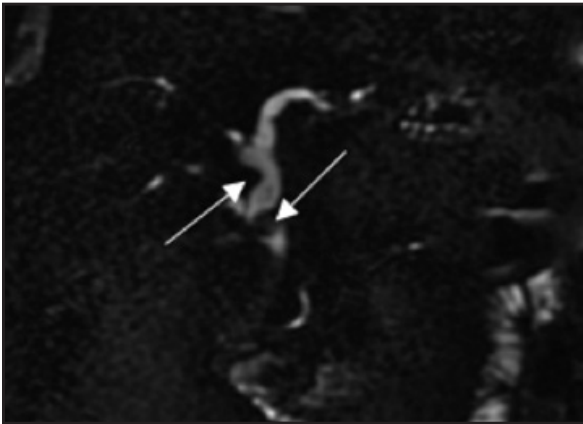
MRI is the preferred second-line modality in the pregnant population, as it provides excellent soft-tissue resolution



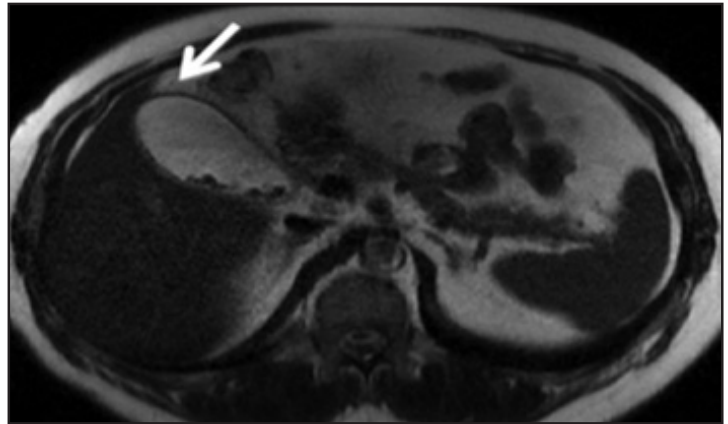
**FIGURE 1.** Normal appendix. Coronal SSFSE image demonstrates an air-filled blind-ending tubular structure arising from the cecum < 6 mm without surrounding inflammatory changes.



**FIGURE 2.** Acute appendicitis. A 22-year-old woman with right lower quadrant pain during the 13th week of pregnancy. Coronal SSFSE (A) and axial fat-suppressed FIESTA (B) images show a dilated, thick-walled and fluid-filled appendix (white arrows) with surrounding inflammatory change (black arrows).



**FIGURE 3.** Choledocholithiasis. A 28-year-old woman presented with right upper quadrant pain, jaundice, and elevated liver function tests. On respiratory triggered magnetic resonance cholangiopancreatography (MRCP), there is dilatation of the intrahepatic and extrahepatic biliary tree due to hypointense stones in the CBD (white arrows).



**FIGURE 4.** Acute cholecystitis. A 38-year-old woman presented during the first trimester with fever and right upper quadrant pain. Axial T2-weighted images through the gallbladder show gallstones, mild wall thickening and a small amount of pericholecystic fluid (white arrow).

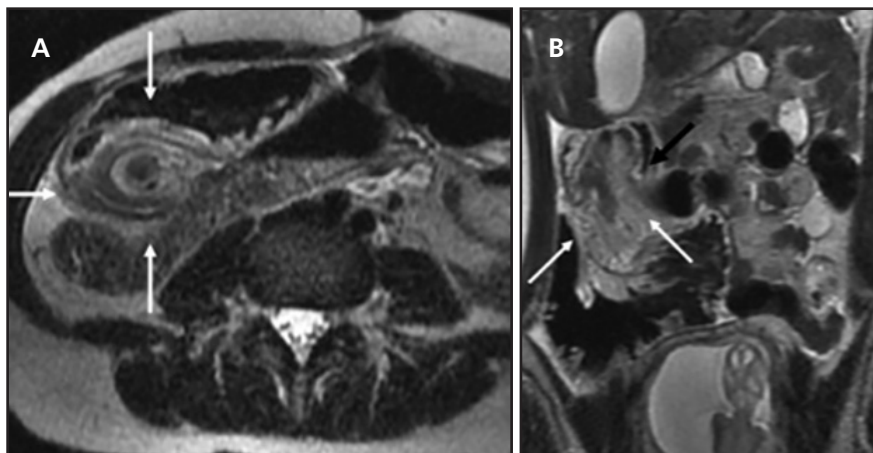
and anatomic detail. Furthermore, its efficacy in evaluating acute abdominal pain can match CT in identifying certain causes of abdominal pain. MRI has 50% to 100% sensitivity, 93% to 100% specificity, 94% to 100% negative predictive value (NPV), and 82% to 100% positive predictive value (PPV) with regard to the diagnosis acute appendicitis.<sup>7</sup> To date, there are no known harmful effects to the fetus at 1.5 Tesla imaging. Potential safety issues include heating effects and acoustic noise, but recent studies have not confirmed these concerns. In fact, the American College of Radiology (ACR)

recommends MRI over CT in pregnant patients when US is nondiagnostic.

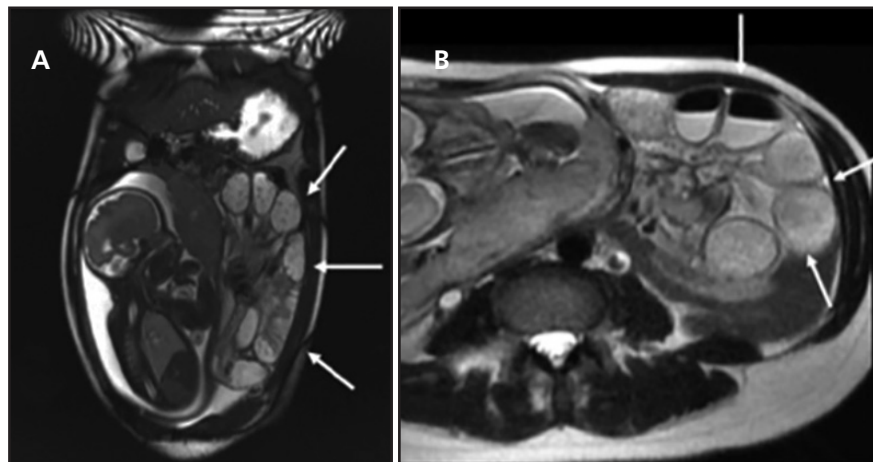
The imaging protocol for MRI evaluation includes T1- and T2-weighted sequences using 1.5 T magnet and a phased array coil. Informed consent should be obtained. Oral contrast is administered at some institutions with iron-oxide-based oral preparations, resulting in a T2\* blooming artifact that aids in identifying the normal appendix. However, recent studies have shown a high accuracy of MRI even without the use of oral contrast, especially in identifying the abnormal appendix. MRI

without oral contrast shortens the time to complete imaging by 1 to 1.5 hours and keeps the patient in a fasting state in case emergency surgery is required.<sup>8</sup>

Single shot fast spin echo sequences (SSFSE), rapidly acquired in all 3 planes, are the most important MRI sequences in the evaluation of the appendix. Rapid acquisition sequences are less prone to artifact from fetal motion or maternal breathing. The disadvantage includes potentially greater deposition of radiofrequency energy. These images are invaluable for assessing the bowel, appendix, solid organs, and ovaries.



**FIGURE 5.** Cecal volvulus. A 35-year-old woman presented during the 14th week of pregnancy with right lower quadrant pain. Axial (A) and coronal (B) SSFSE images show swirling of mesentery (white arrows) and bowel in the right lower quadrant with thickening of the right colon (B, black arrow). At diagnostic laparoscopy, cecal volvulus was confirmed and the patient underwent right hemicolectomy with ileocolic side-to-side anastomosis.



**FIGURE 6.** Closed-loop small bowel obstruction. A 33-year-old woman presented during the 29th week of pregnancy with nausea and vomiting. She had multiple previous cesarean section surgeries. Coronal FIESTA (A) and axial SSFSE (B) images demonstrate dilated loops of small bowel with a clustered radial appearance (white arrows), mesenteric edema, and fluid. Intraoperative findings noted an obstruction due to adhesions and a transition point in the proximal ileum.

Fat saturated T2 or short tau inversion recovery (STIR) images enable detection of subtle inflammation, edema or free fluid. The ovaries, which may be difficult to identify on SSFSE images, are better detected on these sequences.

Axial T1-weighted in-phase and opposed-phased GRE sequences enable delineation of the appendix and provide information about fat and blood-containing structures. Magnetic susceptibility enables identification of air, blood products and calcium.

Time-of-flight imaging enables distinction between the appendix and pelvic vessels. Normal vessels are hy-

perintense, while a normal appendix may be air- or fluid-filled.

## Causes of Abdominal Pain in the Pregnant Patient

### Gastrointestinal Causes

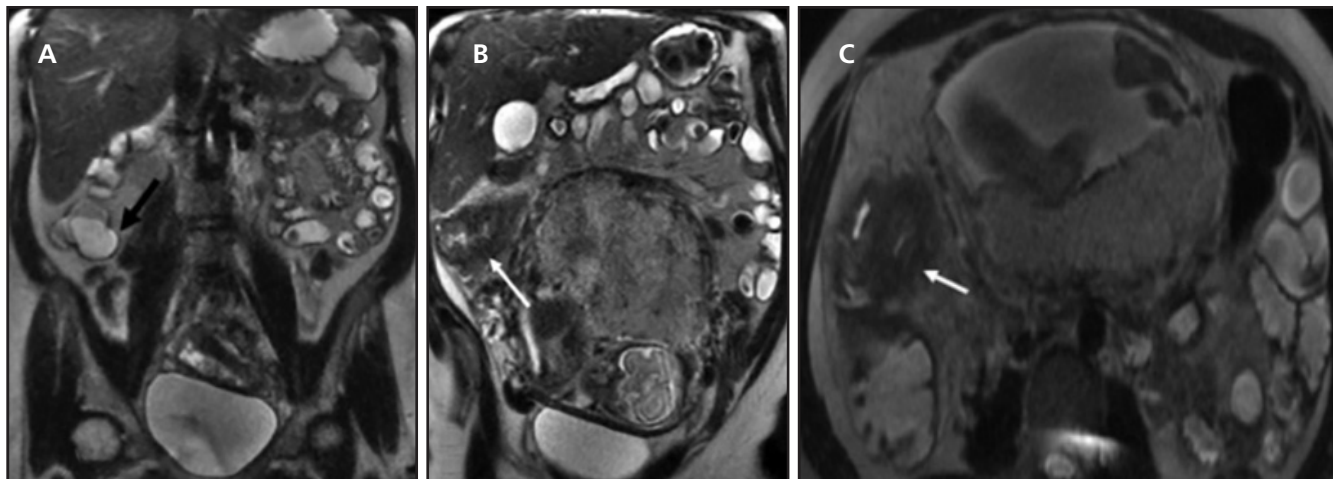
**Acute Appendicitis**—The most common cause of acute abdominal pain in pregnancy is acute appendicitis, affecting as many as 1 in 766 pregnancies.<sup>8-9</sup> Rapid and early diagnosis is crucial in the pregnant patient due to the risk of fetal mortality associated with perforated appendicitis, with rates of fetal loss ranging from 6% to 37%.<sup>10-11</sup> The symptoms are often vague and difficult

to distinguish from physiologic symptoms of pregnancy. Nausea, vomiting, peritoneal signs, and mildly elevated white count may be seen with the pregnant state, as well as with an underlying infectious process. The appendix may be variable in location and is often displaced into the right middle or upper abdomen by the gravid uterus, especially during the late third trimester.

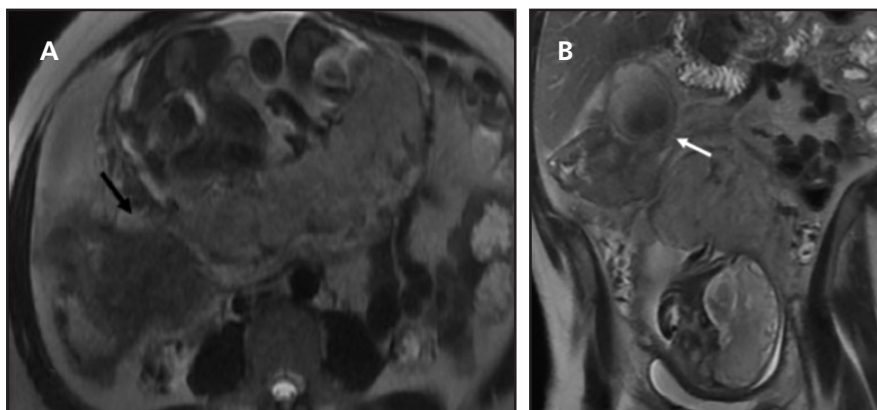
On MRI, the normal appendix appears as a tubular, blind-ending structure arising from the cecum, filled with fluid, contrast, or air (**Figure 1**). MRI findings of acute appendicitis include a dilated appendix (> 7 mm), wall thickening (> 2 mm), high signal intensity intra-luminal fluid, appendicolith, and surrounding inflammatory changes (**Figure 2**). An appendiceal caliber of 6-7 mm is considered indeterminate for appendicitis. Without signs of periappendiceal fat stranding, abscess, or wall thickening, these patients should be followed with close observation and serial abdominal examinations.

**Gallbladder and Biliary Tract Disease**—Gallstones and biliary sludge are the primary cause of most gallbladder-related pain. Multiparity is considered a risk for gallstone development. Asymptomatic stones are seen in 3.5% to 10% of pregnancies, while the incidence of gallbladder disease in pregnancy is 0.05% to 0.3%.<sup>12</sup> Gallstones can present as obstructive disease with cystic duct obstruction and cholecystitis or choledocholithiasis (**Figure 3**). Acute cholecystitis is seen on MRI as gallbladder distention with stones, wall thickening, and surrounding edema (**Figure 4**). Complications of choledocholithiasis include cholecystitis, pancreatitis, and ascending cholangitis.

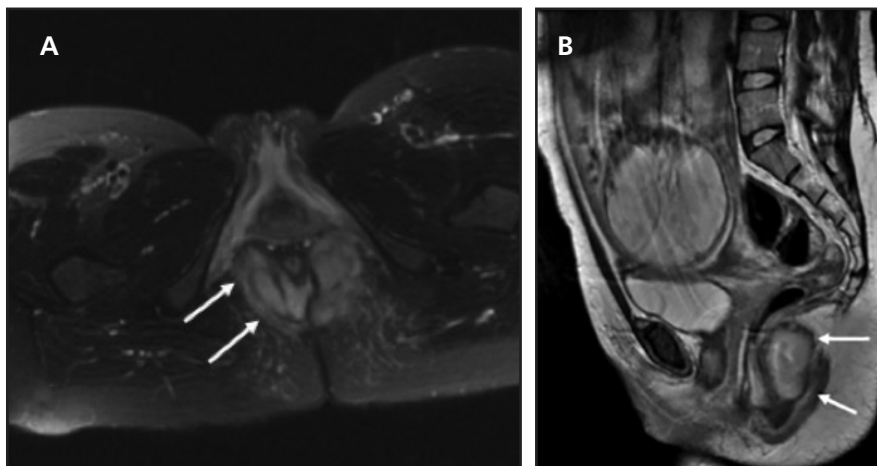
**Bowel Obstruction**—Bowel obstruction in pregnancy is uncommon, with a prevalence of 1 in 2500 to 16,709 deliveries.<sup>13</sup> Abdominal distention and displacement of viscera by the gravid uterus may alter the typical signs of acute abdomen and mimic other pregnancy-related symptoms, making the diagnosis of bowel obstruction difficult.



**FIGURE 7.** Inflammatory bowel disease. This is a 36-year-old woman with right lower quadrant pain during the second trimester with a mass seen at appendectomy. Coronal (A, B) and axial (C) SSFSE images after administration of T2 hyperintense VoLumen contrast demonstrate a normal cecum (A, black arrow) and thickening of the terminal ileum (B, white arrows). Tissue sampling at ileocolonoscopy diagnosed her with Crohn's disease.



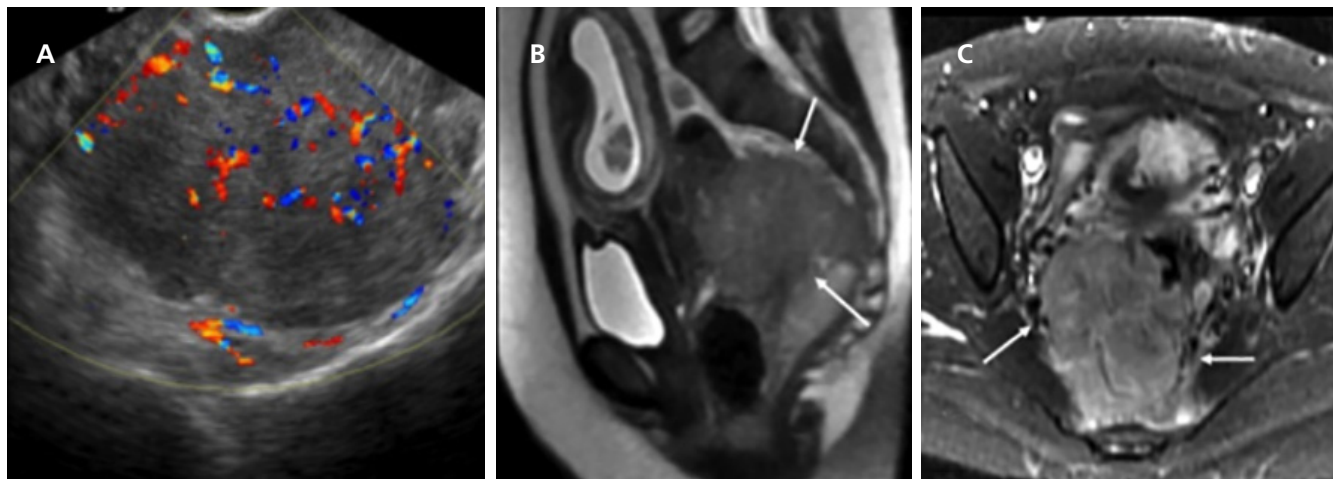
**FIGURE 8.** Crohn's disease complicated by abscess. The same patient in Figure 7 returned 1 month after medical therapy with right upper quadrant pain and fever. Follow-up imaging with axial (A) and coronal (B) SSFSE images demonstrate persistent terminal ileal thickening (A, black arrow) and interval development of a heterogeneous collection in the right upper quadrant compatible with abscess (B, white arrow).



**FIGURE 9.** Perirectal abscess. A 29-year-old woman in her 31st week of pregnancy presented with constipation and pain on defecation. Fat suppressed axial SSFSE (A) and sagittal SSFSE (B) images demonstrate a multiloculated perirectal collection consistent with intersphincteric abscess (white arrows). She underwent incision and drainage.

Adhesions are the most common cause of bowel obstruction in pregnancy, especially in the third trimester, accounting for more than half of the cases.<sup>14</sup> Volvulus (**Figure 5**) is the second most common cause of bowel obstruction in pregnancy, representing 25% of cases as compared to 3% to 5% in nonpregnant women. There is also a significantly higher mortality rate (3% to 15%) of midgut volvulus in pregnancy compared to the general population.<sup>15</sup> Other causes of bowel obstruction include intussusception (5%), hernia (3%), appendicitis (1%), carcinoma (1%), and idiopathic ileus (8%).<sup>16</sup> A high degree of suspicion is crucial to ensure prompt diagnosis and appropriate therapy, especially in pregnant patients with a history of previous abdominal surgery. MRI demonstrates proximal bowel dilatation with delineation of the transition point in cases of high-grade obstruction. In closed-loop obstructions, there is a radial array of bowel with mesenteric edema and mesenteric whirling (**Figure 6**).

**Inflammatory Bowel Disease**—Inflammatory bowel disease (IBD) has a peak incidence during the reproductive years. About two-thirds of women in remission stay in remission.<sup>17</sup> In some cases, inflammatory bowel disease may improve during pregnancy as the body suppresses the immune system to prevent it from rejecting the fetus. It has



**FIGURE 10.** Rectal mass in pregnancy. A 40-year-old woman presented in her 11th week of pregnancy with bloody diarrhea. US (A) showed a vascular rectosigmoid mass. Sagittal (B) and axial (C) MR images showed a soft-tissue mass arising from the rectosigmoid colon (white arrows). Biopsy revealed squamous cell carcinoma.

been suggested that pregnancy may also protect against future flares. However, pregnant patients with severe IBD flares may be at an increased risk of miscarriage and low birth weight.<sup>18</sup>

IBD, particularly Crohn's disease (CD), can involve any site of the gastrointestinal tract from the mouth to anus, and is associated with serious complications, such as strictures, perforation, and fistulae.<sup>19</sup> The terminal ileum is involved in most cases of Crohn's disease with mural thickening, edematous walls, luminal narrowing, and surrounding edema and free fluid (Figure 7). Complications include abscess and fistula formation (Figures 8 and 9). High-resolution MRI is ideal for delineating fistulae. Active perianal disease at delivery is an indication for cesarean section.

**Colorectal Cancer**—Colorectal cancer (CRC) is rare in pregnancy with an incidence of 0.008% or 1 in 13,000 pregnancies.<sup>20-21</sup> The mean age of women with colon cancer during pregnancy is about 31 years (range of 16-48 years).<sup>22</sup> CRC can mimic the signs and the symptoms of pregnancy. For example, spasmodic abdominal pain due to partial large bowel obstruction may present as uterine cramps; anemia from colon cancer may be assumed to represent physiological anemia of pregnancy; and rectal bleeding or pain may be misdiagnosed as engorged hemor-

rhoids or anal fissures. Consequently, CRC is typically diagnosed at an advanced stage with a poor outcome for the mother and the fetus with the median survival of < 5 months.<sup>23</sup>

The typical diagnostic tests such as sigmoidoscopy/colonoscopy or CT colonoscopy are relatively contraindicated in pregnancy due to fetal exposure to potential teratogens. MRI can help avoid radiation, and stage the rectal disease and metastasis in pregnant patients (Figure 10). Treatment decisions are made depending on legal, ethical, personal, religious, and emotional factors.<sup>24-26</sup> Because treatment delay may lead to disease progression in the first 20 weeks of pregnancy, thus compromising the mother's life, pregnancy termination to initiate cancer treatment is considered as early as possible. Surgery and treatment can be delayed to save the fetus in the later pregnancy.<sup>25</sup>

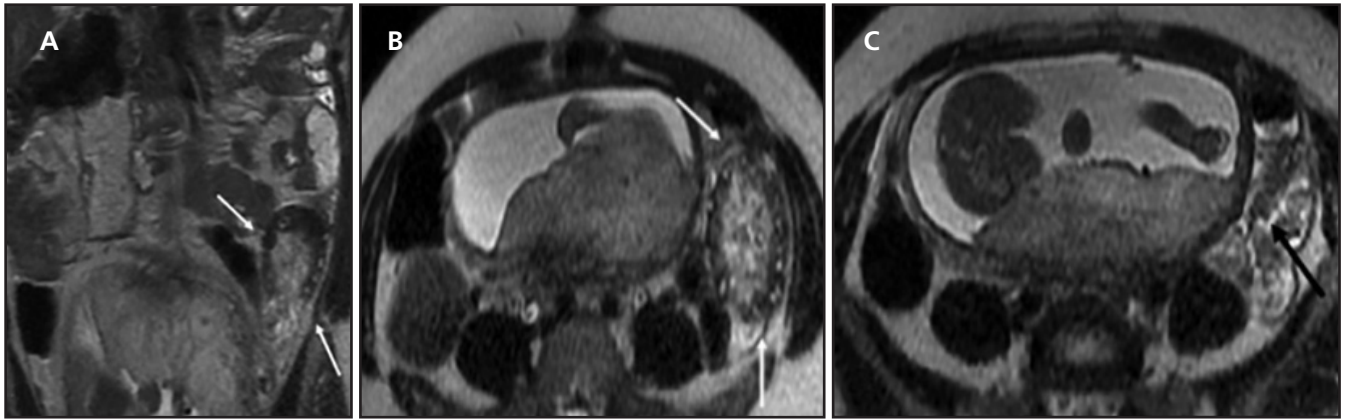
#### Genitourinary Causes

MRI is helpful for evaluating genitourinary causes of abdominal pain. MRI can distinguish between physiologic and obstructive hydronephrosis. Physiologic hydronephrosis is common in pregnancy, due to a combination of hormone-related relaxation of the ureters and extrinsic compression by the uterus, usually on the right side. Renal stones affect as many as 1 in 200 pregnancies.<sup>28</sup> US is the preferred modality

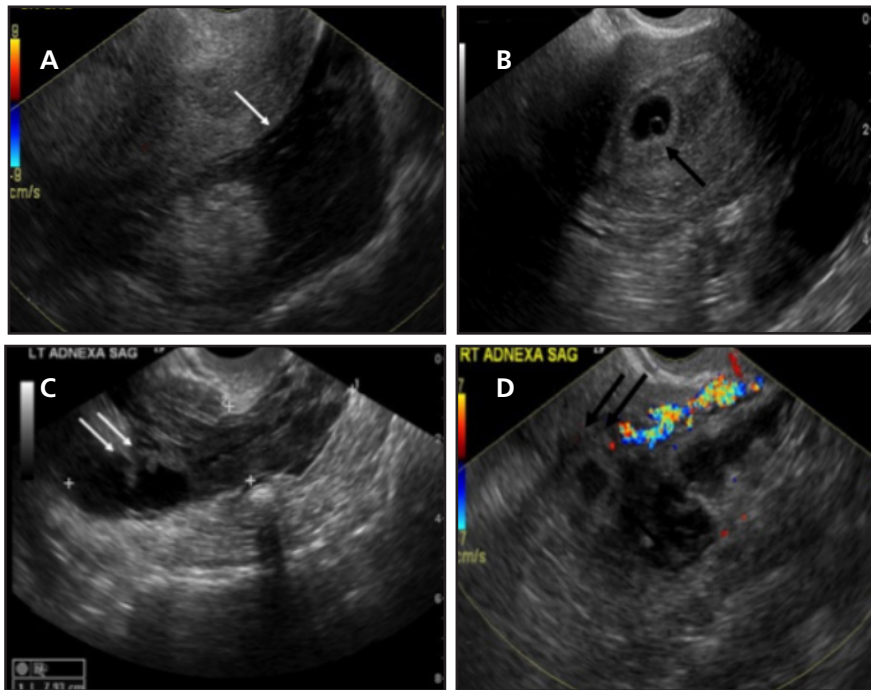
with variable sensitivity in the detection of stones. Elevated resistive indices of renal parenchyma can be found in the obstructed kidney. Documentation of ureteral jets can exclude obstruction, although they are not always visualized, even in healthy patients, as frequency of ureteral jets may range from seconds to minutes and are influenced by hydration status.<sup>29</sup> Repositioning of the patient to the contralateral decubitus view may help improve visualization of the ureteral jet. In obstructive hydronephrosis, there are secondary signs such as perinephric fluid, renal enlargement and edema, as well as abrupt change in ureteral caliber. Occasionally, the stone may be seen as a dependent round intraluminal filling defect.

**Gynecologic Disease—Hemorrhagic Ovarian Cyst:** Hemorrhagic ovarian cysts are a common cause of right lower quadrant pain, frequently resulting from rupture into the peritoneal cavity. MRI findings include complex free pelvic fluid without or with visualization of a complex ovarian cyst. Complex cysts demonstrate heterogeneous T2 signal and are usually associated with paraovarian free fluid.

**Ovarian Torsion:** Approximately 70% to 80% cases of adnexal torsion occur in women of reproductive age, and 12% to 25% of women with torsion are pregnant.<sup>30</sup> Torsion is commonly



**FIGURE 11.** Ovarian torsion. A 33-year-old woman with left lower pelvic pain. The left ovary was not visualized on ultrasound. Coronal (A) and axial (B and C) T2 MR images showed an enlarged edematous left ovary with peripheral displacement of follicles (A, B, white arrows) and thickening of the fallopian tube (C, black arrow). Diagnostic laparoscopy confirmed ovarian torsion.



**FIGURE 12.** Heterotopic pregnancy. A 28-year-old woman presented with severe abdominal pain. She had no prior history of in-vitro fertilization. The serum b-HCG was 14,000. Sonographic images demonstrated a moderate volume of hemoperitoneum in the cul-de-sac (A, white arrow). There was an intrauterine gestational sac (B, black arrow). The left adnexa demonstrated mild hydrosalpinx (C, double white arrows). In the right adnexa (D, double black arrows), there was a thick rimmed cystic structure in the setting of hydrosalpinx, concerning for a tubal ectopic pregnancy. Laparoscopic examination revealed active bleeding from the right fallopian tube compatible with a ruptured ectopic pregnancy.

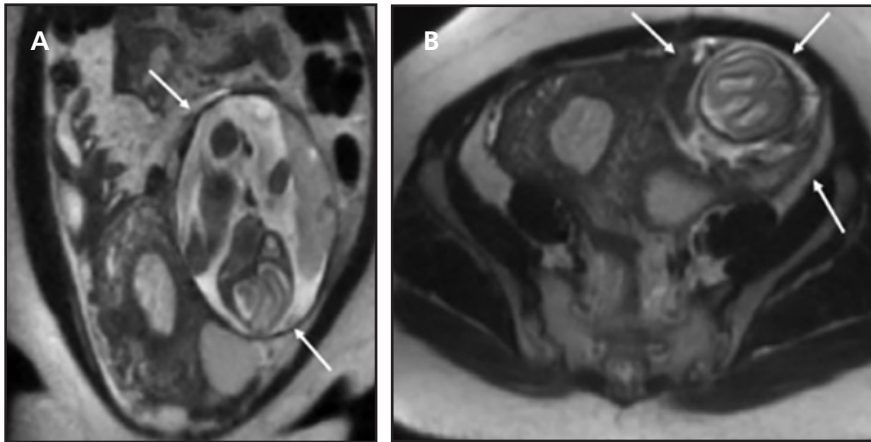
associated with an increase of ovarian size and weight. While ovarian masses have been considered major risk factors, ovarian hyperstimulation is another major risk factor for adnexal torsion in up to 10-20% of pregnant patients due to the growing prevalence of fertility treatment.<sup>31</sup> Recurrence of ovarian torsion also occurs more frequently in pregnant

patients, in particular with enlarged multicystic ovaries.<sup>32</sup>

As patients with ovarian torsion may present with nonspecific clinical features and laboratory markers without clear sonographic signs, definitive diagnosis is achieved by surgery. US is readily available and considered the test of choice. Both gray-scale and color

Doppler US have been shown to be accurate for the diagnosis of torsion.<sup>33</sup> US may show an enlarged ovary with edematous stroma and peripheral follicles. The ovaries may be abnormally positioned in the pouch of Douglas, anterior to the uterus, or in the contralateral side. Pelvic free fluid may be seen and is indicative of infarction and hemorrhage. Doppler blood flow may be abnormal or normal; the mere presence of blood flow on Doppler US has a poor negative predictive value.<sup>34</sup> In partial or early torsion, both arterial and venous flow may be maintained with viable ovarian tissue. Absence of arterial and venous blood flow in the twisted pedicle and/or visualization of the flow in the artery alone are predictive of nonviability of the ovary. Similar findings of an enlarged edematous ovary and peripheral arrangement of follicles can be seen on MR (Figure 11). MRI can be particularly helpful in evaluating ovarian masses.<sup>35</sup> In some cases, one may see tubal thickening or dilatation, ipsilateral displacement of the uterus, and adnexal fat stranding.<sup>36</sup>

**Uterine Leiomyomas:** Uterine leiomyomas are common benign neoplasms affecting women of reproductive age and can often enlarge during pregnancy. Enlarging fibroids can outgrow their vascular supply, leading to degeneration. Various types of degeneration can occur, including myxoid degeneration, cystic degeneration, and red degeneration. Red degeneration is a subtype



**FIGURE 13.** Abdominal ectopic pregnancy. Coronal (A) and axial (B) MR images show an empty fluid collection within the enlarged uterus and absence of myometrial tissue surrounding this gestational sac (A, B, white arrows) with intraoperative confirmation of an abdominal pregnancy.

of hemorrhagic infarction that typically occurs during pregnancy. Rapid growth, torsion or degeneration may be the cause of abdominal pain due to fibroids during pregnancy. Patients may present with focal pain, tenderness on palpation, or fever. The diagnosis can typically be made on US by reproducing pain when the probe is placed over the fibroid. In situations where ultrasound is limited, as with a deep pelvic location of the fibroid, MRI may be helpful. High signal intensity on T1 and variable signal on T2 sequences are seen with red degeneration. Diffuse increased signal on T2 may be related to edema prior to degeneration.

### Obstetric Causes

**Ectopic Pregnancy:** Roughly 2% of all pregnancies are ectopic.<sup>37</sup> Despite improvements in treatment, ectopic pregnancy remains the leading cause of maternal mortality during the first trimester of pregnancy. Ultrasound remains the initial imaging modality of choice. If the results of US are nondiagnostic, MRI is often used for further characterization. Hemoperitoneum is nonspecific and may be caused by a hemorrhagic cyst, placenta accreta, spontaneous abortion, and ectopic pregnancy. Ninety-eight percent of ectopic pregnancies occur in the fallopian tubes (**Figure 12**). On MRI, common findings include a T2 high-signal mass with thick-walled ring. Hemorrhagic fluid in

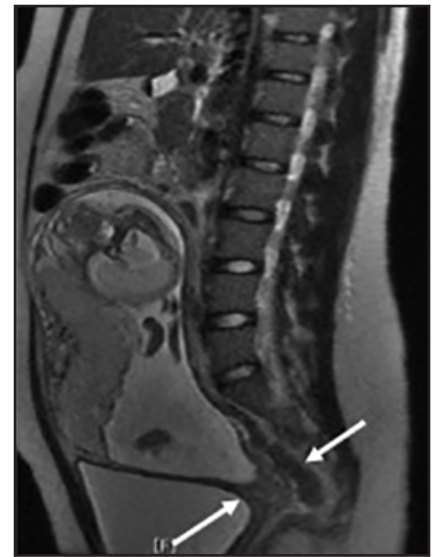
the peritoneal cavity without a clearly identified intrauterine pregnancy has been shown to have a high positive predictive value for ectopic pregnancy.

Abdominal pregnancies account for 1% of ectopic pregnancies with a high maternal mortality risk, as high as 20%. MRI findings include the presence of a gestational sac outside of the reproductive tract, with or without signs of hemorrhage (**Figure 13**). These pregnancies may be diagnosed late in pregnancy, with increased risk of maternal morbidity and mortality.

**Preterm Labor:** Cervical length is inversely proportional to the risk of preterm labor. First trimester cervical length is usually > 50 mm. The cervical length decreases to < 34 mm at 28 weeks' gestation. Multiparous women tend to have shorter cervical lengths.<sup>38</sup> Rates of preterm labor increase significantly in women with a cervical length < 25 mm at 24 weeks' gestation. Imaging signs of preterm labor include cervical shortening, funneling and cervical dilatation (**Figure 14**).<sup>39</sup>

### Summary

US and MRI are the modalities of choice in the evaluation of abdominal pain in pregnant patients. US is invaluable for the evaluation of pelvic causes of acute pain, including ovarian torsion, ectopic pregnancy, and hemorrhagic cysts. In cases of indeterminate ultrasound results, MRI is the second-line



**FIGURE 14.** Premature labor. A pregnant woman presented with severe abdominal pain at 23 weeks' gestation and was found on ultrasound to have a shortened, funneled cervix, confirmed on MRI (white arrows). The baby was delivered a few hours later.

tool due to its high soft-tissue resolution, safety, and ability to illuminate alternate causes of pain. It is especially valuable in evaluating gastrointestinal causes of acute abdominal pain, including acute appendicitis and bowel obstruction without the risks of ionizing radiation to the unborn fetus. SSFSE sequences enable rapid acquisition of images that are less prone to fetal motion or maternal breathing motion artifact. The high resolution does not require oral contrast, saving time and keeping the patient in a fasting state in case emergent surgery is required. As MRI becomes increasingly used to evaluate acute abdominal pain in the pregnant patient, it is imperative that radiologists learn to recognize the MRI features of these common entities to formulate a prompt diagnosis and guide appropriate management for these patients.

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