Imaging of Trauma in the Pregnant Patient[1]

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Abbreviations: FDA = Food and Drug Administration, HASTE = half-Fourier acquisition single-shot turbo spin-echo

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SA-CME LEARNING OBJECTIVES

After completing this journal-based SA-CME activity, participants will be able to:

- Discuss the imaging modalities used in the evaluation of pregnant trauma patients.
- Describe radiation dose–related concerns as they apply to pregnant trauma patients.
- Identify the imaging findings associated with non–pregnancy-related and pregnancy-specific injuries.

See www.rsna.org/education/search/RG.

TEACHING POINTS
See last page

The pregnant trauma patient presents an important and challenging encounter for the clinical team and radiologist. In this article, we present several key aspects of the imaging workup of pregnant trauma patients, beginning with a review of the modalities that are used in this setting. Ultrasonography plays an important role in initial evaluation of the fetus but a limited role in evaluation of maternal injuries. Given that conventional radiography and computed tomography are the "workhorse" modalities for evaluation of pregnant trauma patients, radiologists must pay particular attention to radiation dose concerns. Magnetic resonance imaging can be used after the initial evaluation and for follow-up imaging, and safety concerns related to its use in pregnant patients are addressed. At imaging interpretation, radiologists must contend not only with the typical spectrum of injuries that can be seen in any trauma patient but also with pregnancy-specific injuries, such as placental abruption and uterine rupture. Particularly unusual situations, such as a ruptured ectopic pregnancy in a trauma patient, are presented. Although pregnant trauma patients are infrequently encountered, familiarity with imaging findings of injuries in these patients is essential to providing the best care for the mother and fetus.

Introduction

Trauma, which affects 5%–7% of all pregnancies, is the leading cause of nonobstetric maternal mortality (1–3). Motor vehicle collisions are responsible for over half of the cases of trauma in pregnant patients, but other causes, such as falls, assaults, burns, and other wounds, can contribute to maternal trauma in pregnancy (3). Of course, in the setting of a trauma complicated by pregnancy, there are two patients, and fetal loss rates approach 40%–50% in life-threatening trauma. While fetal loss occurs at a much lower rate with minor injuries (1%–5%), minor injuries are much more common. The net result is that the majority of fetal losses occur after minor trauma (1).

Pregnant trauma patients present an important and challenging encounter for the radiologist. The purpose of this article is to discuss some of the key concepts related to the imaging of pregnant trauma patients. After reviewing the basic principles for the initial management of pregnant trauma patients, we discuss the rationale and approach to imaging evaluation, paying special attention to radiation doses and concerns. This is followed by a short review of non–pregnancy-specific injuries and their relevance in pregnant patients. Pregnancy-specific injuries, including placental abruption and uterine rupture, are also discussed. As the fetus is well protected by the mother's subcutaneous tissue, bony pelvis, uterus, and amniotic fluid, fetal injuries are relatively rare, and specific fetal injuries are not addressed here. At imaging, detection of specific fetal injuries is difficult, although catastrophic injury to the entire fetus can be detected, and fetal skull fractures can occasionally be diagnosed at imaging in the third trimester (1,4).

Initial Management

Teaching Point

The first goal of the medical team caring for the pregnant trauma patient is to stabilize the mother, keeping in mind that maternal demise will almost always lead to fetal demise. Stabilization involves the use of standard resuscitation techniques that would be used with any trauma patient. If the patient is more than 20 weeks pregnant, she should be placed in the 30° left lateral decubitus position to prevent systemic hypotension caused by compression of the inferior vena cava by the gravid uterus. For imaging studies that require the patient to lie flat for an extended time, use of the 30° left lateral decubitus position during imaging should be strongly considered. In addition, blood products should be administered to maintain a hematocrit level higher than 30% for optimal fetal oxygenation (4,5).

After the patient has been stabilized, ultrasonography (US) should be performed to determine the gestational age of the fetus and whether a fetal heart rate is present. For a fetus with a gestational age younger than 24–26 weeks, intermittent fetal monitoring can be performed because the fetus would not be able to survive outside the uterus. For a viable fetus older than 24–26 weeks of gestational age, continuous external fetal monitoring should be used (6).

Imaging Evaluation

The use of imaging studies to evaluate for specific maternal injuries has several important benefits. First, avoiding nonobstetrical laparotomy is beneficial, given that nonobstetrical laparotomy alone results in a 26% incidence of preterm labor in the second trimester and an 82% incidence of preterm labor in the third trimester (7,8). Thus, using imaging studies to exclude injuries or to detect injuries that can be managed nonoperatively is beneficial. Furthermore, early diagnosis of maternal injuries is paramount because shock portends a poor outcome for both the mother and fetus, with fetal death rates approaching 80% (8). The use of imaging studies allows the clinical team to be aggressive and proactive in addressing injuries to avoid the consequences of delayed treatment. Finally, if surgery is required, imaging studies can be used to guide the surgical technique and to ensure that all known injuries are addressed as efficiently as possible.

US Examination

In the acute setting, US frequently is used to evaluate the pregnant trauma patient. During initial evaluation, US is used to assess the fetus and estimate its gestational age. For maternal evaluation, focused assessment with sonography in trauma (FAST) scans can be used to depict intraperitoneal or pericardial fluid. While some authors have reported widely ranging sensitivities and accuracy for the detection of free intraperitoneal fluid via US in the setting of trauma, with some values reported over 90%, others have noted that small amounts of free intraperitoneal fluid (<400 mL) are much more difficult to detect (9–11). The relevance of small amounts of free intraperitoneal fluid is also complicated in the pregnant trauma patient, as small amounts of normal free intraperitoneal fluid are expected in this population. It is important to remember that US is not a substitute for a clinically needed diagnostic computed tomographic (CT) examination, as its performance for detecting solid- and hollow-organ injuries lags substantially behind CT (9,12–14). In pregnant patients, the sensitivity and specificity of US for detecting intra-abdominal injuries range from 61%–83% and 94%–100%, respectively (15–17). Detection of parenchymal injuries, and even hemoperitoneum, requires substantial training and sonographer skill, particularly when the imaging evaluation is performed in the hectic setting of an acute trauma.

Conventional Radiography and CT

The "workhorse" modalities for the imaging evaluation of pregnant trauma patients are conventional radiography and CT. Since both conventional radiography and CT utilize ionizing radiation, it is important to be familiar with the doses of typical imaging examinations and their relationships to the thresholds for deleterious fetal effects. As described in the 2008 American College of Radiology practice guidelines for imaging pregnant or potentially pregnant patients and supported by the American College of Obstetricians and Gynecologists and the National Council on Radiation Protection and Measurements, fetal radiation doses of less than 50 mGy are not associated with increased fetal anomalies or fetal loss throughout pregnancy (18–20). This concept is important because the radiation doses of essentially all diagnostic imaging examinations using ionizing radiation that would be used in a trauma evaluation should be well below this threshold (Table). For imaging examinations in which the fetus is not in the field of view, radiation doses are well below the fetal dose from naturally occurring background radiation during

Teaching Point

pregnancy (0.5–1.0 mGy); for example, a pulmonary embolism protocol chest CT carries a fetal dose of only 0.2 mGy. The estimated radiation dose for a CT of the abdomen and pelvis, with the fetus in view, is higher (25 mGy) but still well below the threshold of 50 mGy. The only imaging situation in which the dose could exceed 50 mGy for a single study would be an extended fluoroscopic examination of the pelvis, particularly if an intervention is performed (21).

In a seriously injured pregnant patient, multiple or repeat imaging examinations could result in a fetal radiation dose that exceeds 50 mGy. In these situations, it is important to recognize the risks of ionizing radiation to the fetus, which depend on the stage of the pregnancy. Less than 2 weeks after conception, the main risk is failure of blastocyst implantation, with the radiation threshold thought to be between 50 and 100 mGy. If the pregnancy survives, there likely is no increased risk for other deleterious effects. From 2 to 20 weeks of gestation, the main fetal risk is teratogenesis. The threshold below which teratogenesis does not occur is not known but is thought to be between 50 and 150 mGy. Finally, carcinogenesis is a risk at any time during pregnancy. The estimated relative risk for fatal childhood cancer after fetal exposure to 50 mGy of ionizing radiation is 2, which represents an increase in the baseline risk from 1 in 2000 to 1 in 1000. A fetal radiation dose of 50 mGy also increases the overall lifetime risk for cancer by 2% (8,23,24).

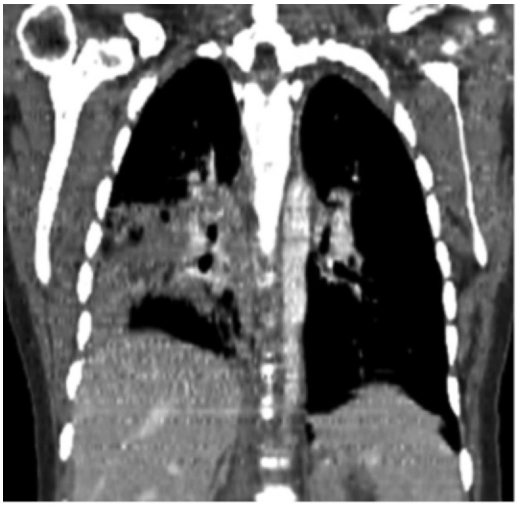
Although the fetal radiation dose for CT examinations almost always falls below the threshold of 50 mGy, it is important to minimize the radiation dose in pregnant trauma patients, particularly given the small but increased risk of carcinogenesis and the high likelihood of the need for additional imaging. CT scans should be modified to use the lowest dose possible, which includes reducing the tube potential (kilovolt peak) and tube current–time product (milliampere-second), increasing the pitch, and decreasing the z-axis coverage. Multiphase CT studies should be avoided unless they are necessary to characterize a known or strongly suspected urologic injury. For pregnant patients who have been exposed to a larger radiation dose or who have specific questions regarding their exposure, appropriate patient counseling is important. Relevant data should be provided, and the patient should be counseled in a nondirective fashion to allow informed decision making. If necessary, a medical physicist can be consulted to obtain the best estimate of the fetal radiation dose. The facts should be conveyed clearly to avoid an unwarranted elective termination of an otherwise wanted pregnancy (23,25).

Estimated Fetal Radiation Dose from Conventional Radiographic and CT Examinations

Examination	Estimated Fetal Dose (mGy)
Radiography	
Cervical spine (AP, lateral)	<0.001
Extremities	<0.001
Chest (PA, lateral)	0.002
Thoracic spine	0.003
Abdomen (AP) (21-cm patient thickness)	1
Abdomen (AP) (33-cm patient thickness)	3
Lumbar spine (AP, lateral)	1
CT	
Head	0
Chest (routine)	0.2
Chest (pulmonary embolism protocol)	0.2
Abdomen	4
Abdomen and pelvis	25
CT angiography of the aorta	34
CT angiography of the coronary arteries	0.1

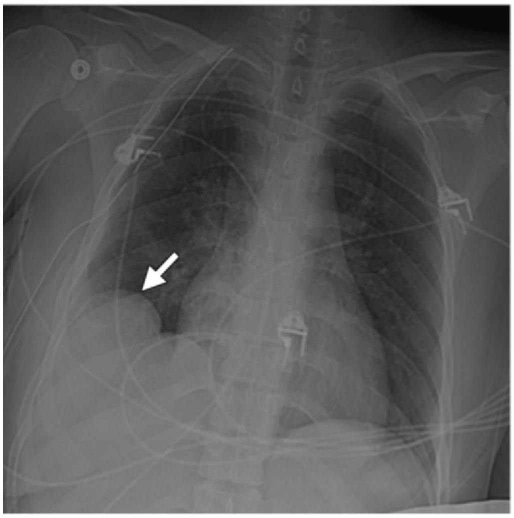
Source.—References 21 and 22.
Note.—The naturally occurring background radiation dose during pregnancy is 0.5–0.1 mGy. AP = anteroposterior, PA = posteroanterior.

Body CT examinations of pregnant trauma patients should be performed with intravenous iodinated contrast, when possible. The use of iodinated contrast improves detection of both maternal and fetal injuries by providing vascular contrast in organs and opacification of vascular structures, including the placenta. Intravenous iodinated contrast material is a U.S. Food and Drug Administration (FDA) category B drug, meaning that it has shown no known adverse effects in animal or human studies. Of note, the intravascular administration of iodinated contrast material to the mother has not been found to affect fetal thyroid function (26–28). The American College of Radiology has concluded that while there is no evidence that iodinated contrast material causes harm to the fetus, there is insufficient evidence to conclude that it poses no risk. Therefore, the use of iodinated contrast material in pregnant patients is recommended when the required information cannot be acquired by using another modality and when the imaging findings will affect the care of the patient and fetus during the pregnancy. As both of these criteria are met in the setting of a pregnant trauma patient who



a.

Figure 1. **(a)** Coronal reconstructed CT image in a pregnant trauma patient who presented with abdominal injuries and pneumothorax (not shown) shows a pulmonary contusion but a normal diaphragmatic contour. **(b)** Follow-up chest radiograph obtained 5 days after **a** shows an abnormal contour in the right hemidiaphragm (arrow). Because the patient was otherwise stable, MR imaging was performed to evaluate the abnormality. **(c)** Coronal T2-weighted half-Fourier acquisition single-shot turbo spin-echo (HASTE) (Siemens Healthcare, Erlangen, Germany) MR image shows herniation of the right hepatic lobe through the diaphragm (arrow), with increased signal intensity in the herniated portion of the liver, a finding consistent with parenchymal edema. Surgical repair of the liver herniation was performed after delivery.



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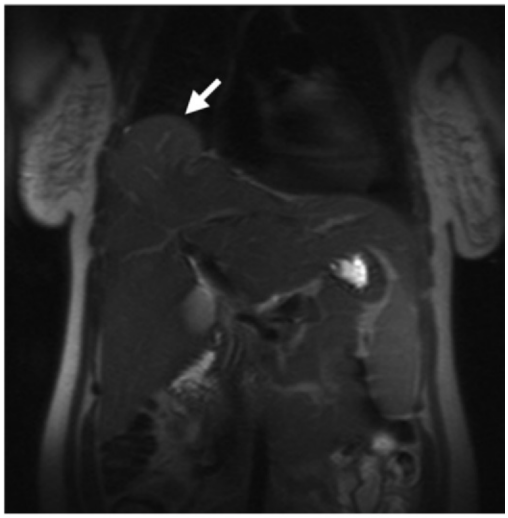


c.

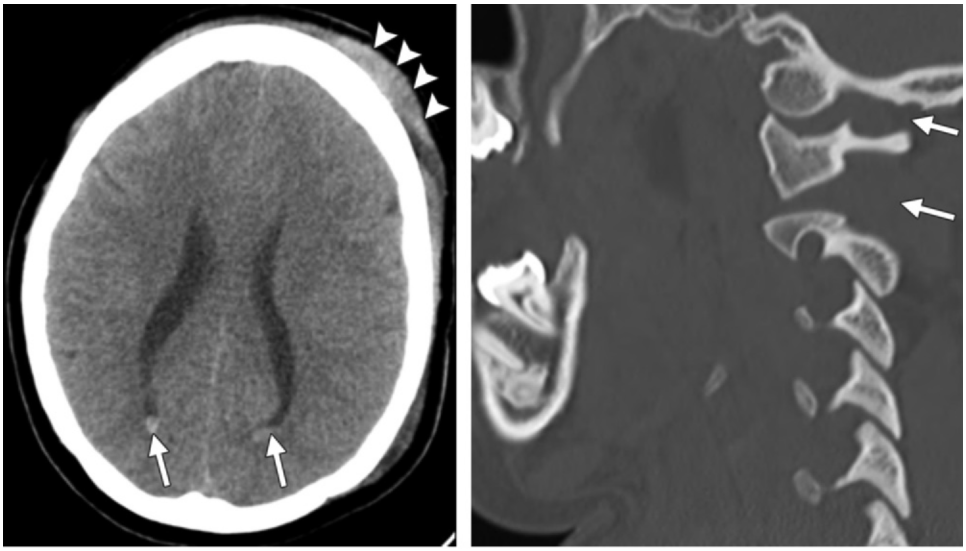
requires a CT examination, iodinated contrast material should be used when necessary. The use of iodinated contrast material to obtain one diagnostic CT study is preferable to obtaining a nonenhanced CT study that may be nondiagnostic and necessitate a repeat study (23,29).

At our institution, gastrointestinal contrast is not routinely administered to trauma patients prior to CT examinations. In cases of penetrating trauma, particularly penetrating trauma in the pelvis, oral and/or rectal contrast can be helpful in the detection of bowel injuries and can be administered if felt to be necessary by the radiologist or clinical team. There are no adverse effects or risks associated with administering oral or rectal contrast to pregnant trauma patients.

Magnetic Resonance Imaging

Given long examination times and the need to remove the patient from the acute care setting, magnetic resonance (MR) imaging is typically not used in the initial evaluation of pregnant patients involved in trauma. After the initial evaluation, MR imaging can be an excellent choice in specific situations, including spinal, complex neurologic, and soft-tissue injuries. MR imaging may also have a role in reducing radiation exposure in patients who require follow-up imaging of injuries diagnosed atinitial presentation, or in stable patients who develop new pain or concerning symptoms after an initially negative evaluation (Fig 1).

In the most recent American College of Radiology white paper for safe MR practices published in 2013 (30), the use of MR imaging was deemed acceptable at any stage of pregnancy if the risk-benefit ratio to the patient warrants that the study be performed and if the required information cannot be obtained with another modality that does not use ionizing radiation. Although there is no evidence of harmful effects to the fetus as a result of MR imaging, the main concerns are the potential effects of energy deposition and resultant tissue heating in the fetus and the potential effects of acoustic noise



a. b.

Figure 2. CT findings in a 20-year-old pregnant patient who was struck by a car. **(a)** Axial CT image shows traumatic head injuries, including a large scalp hematoma (arrowheads) and intraventricular hemorrhage (arrows). **(b)** Sagittal CT image of the cervical spine shows widening of the relationship of C1 to the occiput and of C1-C2 (arrows), findings consistent with atlanto-occipital and atlantoaxial subluxations. The patient underwent spinal fusion after an emergency cesarean section.

(31–33). To minimize these potential risks, it is recommended that MR imaging of pregnant patients is performed at field strengths of 1.5 T or less. In addition, MR imaging protocols for pregnant patients should be tailored to include the minimum number of sequences required to answer the particular clinical question. Gadolinium is considered a pregnancy category C drug by the FDA, which means that animal studies have shown adverse effects but adequate data are not available in humans, and the potential benefits may warrant its use in pregnant women if it is considered critical for evaluation. Typically, the use of gadolinium-based contrast material is not necessary in pregnant trauma patients because essential clinical information can be obtained with nonenhanced MR imaging. Gadolinium-based contrast material can be used for imaging pregnant trauma patients in rare circumstances when it is believed to be absolutely necessary for diagnosis (34).

Non–pregnancy-related Injuries

Radiologists must identify non–pregnancy-related injuries as expeditiously as possible. Intracranial injuries are the major cause of maternal deaths, and CT is the preferred modality for evaluation of suspected intracranial pathology (4). Initial evaluation of spinal injuries can also be performed with CT, bearing in mind that if chest, abdominal, or pelvic CT scans have already been performed to evaluate for other injuries, spinal images should be reconstructed from that dataset rather than performing a dedicated imaging study of the spine (Fig 2). MR imaging can be used for patients with more complex spinal injuries or those in whom spinal cord injury is suspected (Fig 3).

Likewise, the first-line imaging choice for suspected injuries in the chest, abdomen, and pelvis is intravenous contrast-enhanced CT. If pelvic fractures are encountered, a CT cystogram should be considered, as the bladder is compressed by the gravid uterus and may be displaced out of the pelvis later in pregnancy, potentially increasing its risk of injury (35,36). CT cystogram technique can be modified to reduce dose using commercially available dose reduction algorithms as well as by increasing the noise index, as described by Sadro et al (37). MR imaging can be considered if follow-up examinations of the chest, abdomen, and pelvis are needed or for use in stable patients with a low suspicion of injury.

Although the spectrum of injuries in pregnant and nonpregnant trauma patients is the same, the pattern of injuries can be different. In a retrospective assessment of 114 injured pregnant patients compared with injured nonpregnant patients, the pregnant patients were more likely to sustain serious abdominal injuries and less likely to sustain severe chest and head injuries (38). Several authors have speculated that the increased incidence of abdominal injuries may be due in part to the physiologic changes that occur during pregnancy.

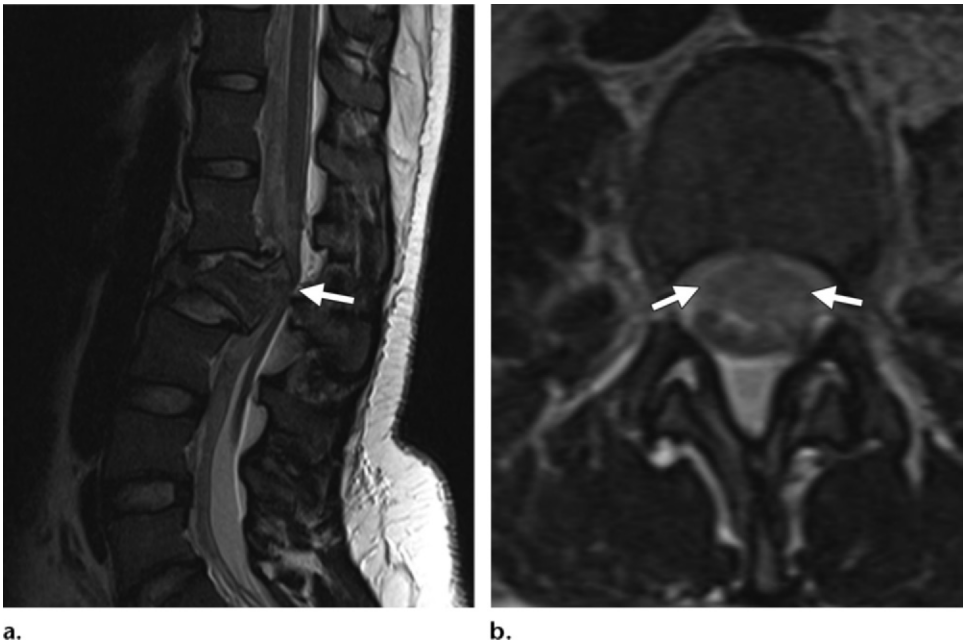


Figure 3. Spinal injury in an 18-year-old pregnant patient who was involved in a motor vehicle collision that involved a 25-foot fall. **(a)** Sagittal T2-weighted MR image shows an L2 burst fracture (arrow) with retropulsion into the spinal canal and severe compression of the central spinal canal. **(b)** Axial T2-weighted MR image shows a large epidural hematoma (arrows) just below the fracture, which also is severely compressing the central spinal canal.

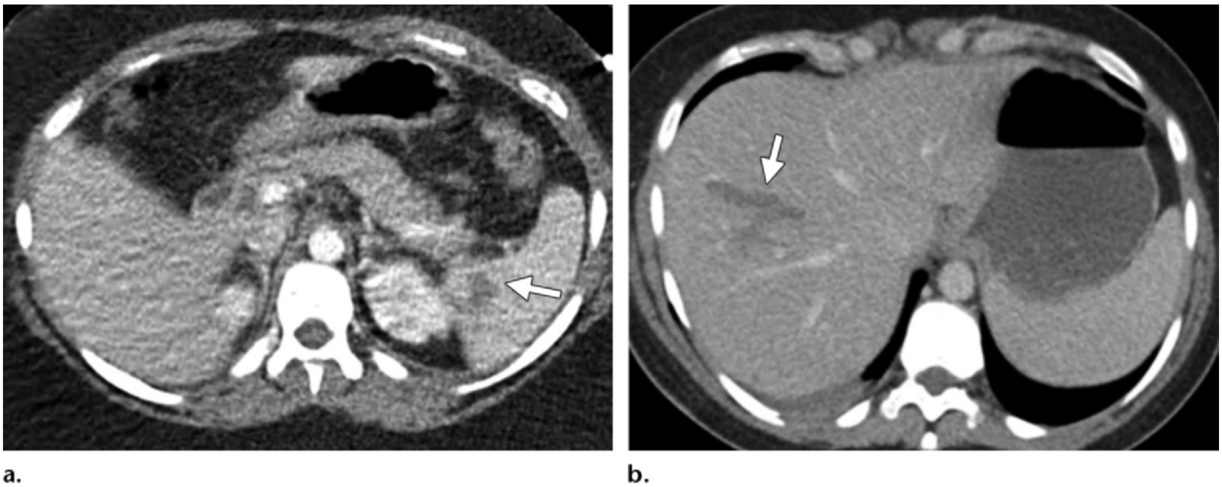
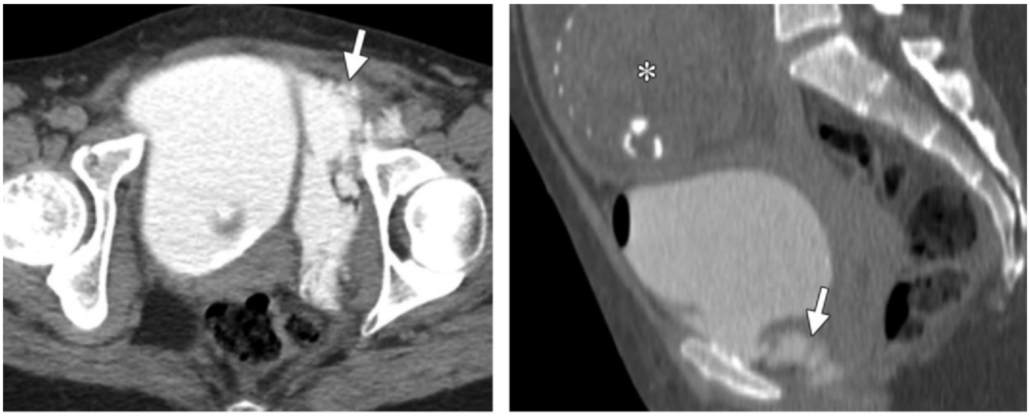


Figure 4. **(a)** Axial CT image in a 24-year-old pregnant patient who was involved in a motor vehicle collision shows a grade 2 splenic injury (arrow). **(b)** Axial CT image in a 29-week-pregnant woman who was involved in a motor vehicle collision shows a grade 3 liver injury (arrow). For both patients, injury characterization with CT allowed appropriate monitoring and avoidance of unnecessary laparotomy.

The spleen enlarges, and the gravid uterus displaces the spleen and liver to positions closer to the rib cage, which increases the possibility of injury (Fig 4). During the later stages of pregnancy, hydronephrosis of pregnancy increases the risk for collecting-system injury. The ovarian and other pelvic veins are also engorged, which may increase the risk for hemorrhage after blunt or penetrating trauma. Particularly later in pregnancy, the bowel is displaced superiorly, which increases the potential for complex and multiple intestinal injuries from penetrating trauma. Also, as the uterus enlarges, the bladder is compressed and can be displaced from the abdomen, which potentially places it at greater risk of injury (4,6,8,35,39) (Fig 5).

Injuries to the bony pelvis present a particularly difficult challenge in the pregnant trauma patient. Pelvic injuries carry a substantially increased risk of fetal demise (up to 35% in more recent reports) and can be difficult to manage

Figure 5. Bladder injury in a 29-week-pregnant woman with pelvic fractures sustained in a motor vehicle collision. Axial **(a)** and sagittal reformatted **(b)** CT cystograms show a large extraperitoneal bladder rupture extending from the anterior bladder near the base, with leakage of contrast agent and urine into the left extraperitoneal pelvis (arrow). Note the compression of the bladder by the gravid uterus (* in **b**) superiorly. The CT findings allowed nonsurgical management, and the fetus was delivered by cesarean section 9 weeks later.



a. **b.**

in pregnant patients who, in addition to being at risk for bladder injuries, are also at risk for significant hemorrhage due to the engorged pelvic vasculature. Maternal mortality is considerable in the setting of pelvic fractures and has been reported to be as high as 9%. Pelvic fractures can also be associated with direct fetal injuries, including skull fractures later in pregnancy. Of note, there is no increased risk for fetal demise in women with complex rather than simple pelvic fractures (35,40).

Pregnancy-specific Injuries

Placental Abruption

Subchorionic placental abruption can occur after trauma because the placenta is more rigid than the uterine wall, which may allow shearing forces to separate the placenta and uterus (6). Placental abruption is the most common cause of fetal death in cases where the mother survives, with a 67%–75% rate of fetal mortality for placental abruption incurred by trauma (8,38). If the fetus survives, low birth weight and preterm delivery are additional complications of placental abruption (41–43). Placental abruption is more common after 16 weeks of gestation and occurs in up to 1%–5% of minor traumas and 20%–50% of major traumas (4). Subchorionic placental abruption can occur either at the margin of the placenta and uterus (marginal abruption) or centrally (retroplacental abruption), with retroplacental abruption typically carrying a worse prognosis. Furthermore, the degree of uteroplacental separation has been found to have an adverse effect on fetal outcome, with increased rates of preterm delivery and fetal loss with greater separation (41). It is important to diagnose placental abruption as rapidly as possible because fetal death can be prevented with emergency cesarean delivery (44).

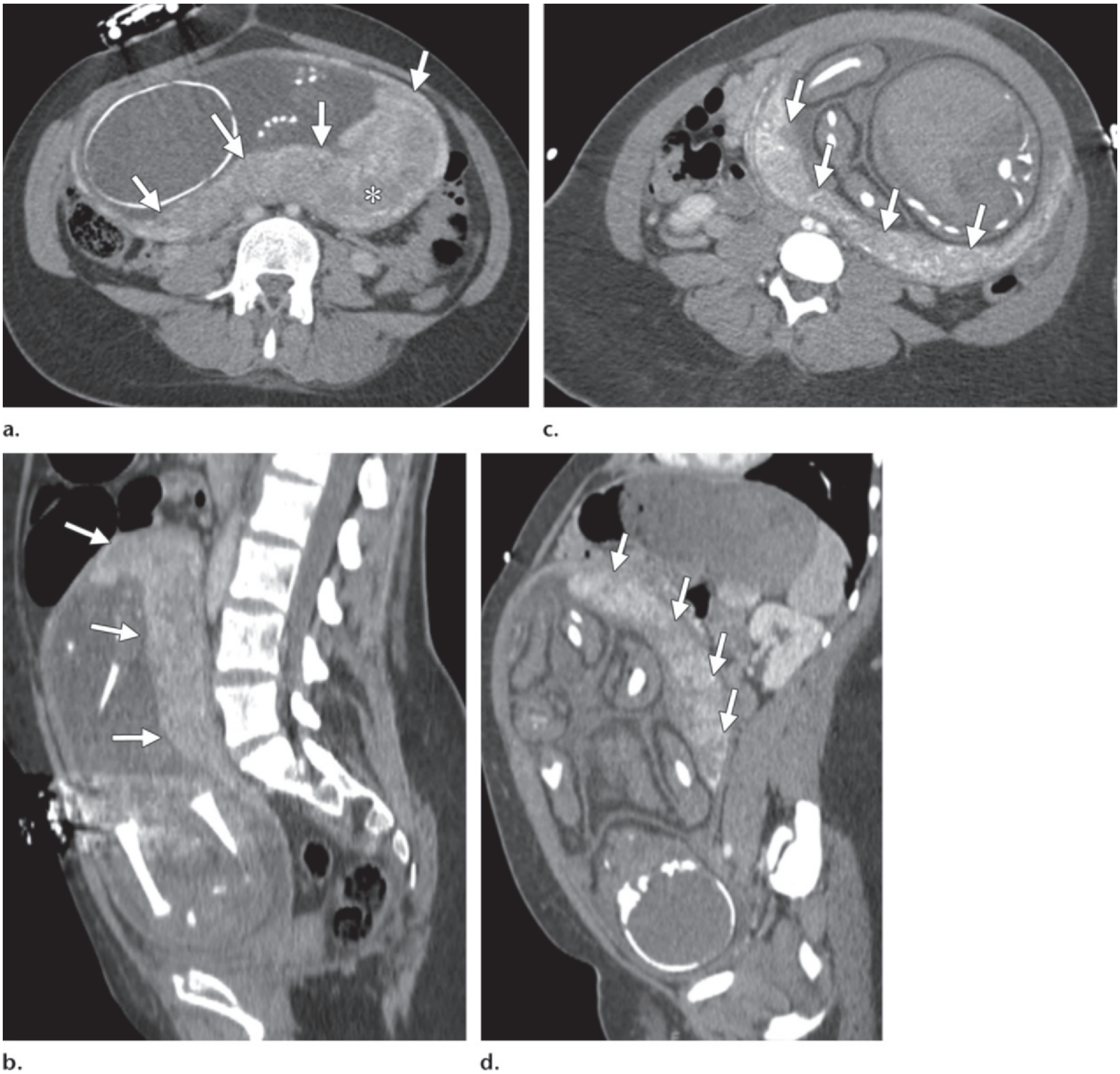
Although US can be used to evaluate the fetus in the setting of trauma, it is not sensitive for the diagnosis of placental abruption, and false-negative findings of 50%–80% have been reported (37,45). Signs of placental abruption that can be identified at US (although they are insensitive for diagnosis) include retroplacental hemorrhage and echogenic amniotic fluid or bowel due to bleeding into the amniotic cavity and fetal swallowing of blood products (37,46). At US, a retroplacental hemorrhage appears hyperechoic to isoechoic relative to the overlying placenta in the acute stage but gradually becomes progressively hypoechoic and eventually sonolucent during the 2 weeks after injury (46).

CT examinations, although typically performed to diagnose other injuries, can demonstrate findings indicating the presence of placental abruption. Although the few studies that have examined the performance of CT in diagnosing placental abruption suffer from low patient numbers, sensitivities of 86%–100% and specificities of 80%–98% have been reported in studies where retrospective assessment of CT scans specifically for the purpose of diagnosing placental abruption was used in the analysis (47,48). It should be noted that when examining original dictated reports, radiologists did not perform as well, with a sensitivity of 43% and a specificity of 90% reported by Wei et al (47).

Familiarity with the imaging appearance of the normal placenta at CT as well as with findings of placental abruption will improve the likelihood

RadioGraphics

Figure 6. **(a, b)** Axial **(a)** and sagittal **(b)** CT images show the normal appearance of the placenta (arrows) at 28 weeks of gestation. **(c, d)** Axial **(c)** and sagittal **(d)** CT images in a different patient show the normal appearance of the placenta (arrows) at 40 weeks of gestation. The normal placenta has diffuse enhancement, which can be somewhat heterogeneous, and it may have rounded areas of lower attenuation due to the placental cotyledons (* in **a**). Fetal enhancement is much more variable, and a lack of enhancement should not be assumed to be due to a lack of blood flow. In **a–d**, the fetuses appear to have decreased or absent enhancement, but both are healthy pregnancies.



of the radiologist making a prospective diagnosis of placental abruption. The appearance of the normal placenta evolves during pregnancy. In the first trimester, the placenta has a homogeneous appearance and often is indistinguishable from the myometrium until the late first trimester. During the second trimester, the placenta becomes more heterogeneous and is easily identified as hyperattenuating relative to the subjacent myometrium on contrast-enhanced CT images. The placental cotyledons begin to form during the second trimester and can be seen as foci of rounded low attenuation surrounded by the enhancing placenta. The heterogeneity of the placenta often increases during the third trimester, and venous lakes can begin to be seen on the maternal side (47,49) (Fig 6).

Several findings of placental abruption may be seen on CT images. Placental abruption is best characterized on CT images as a contiguous retroplacental or full-thickness area of decreased enhancement that forms acute angles with the myometrium (47). Occasionally, areas of contrast agent extravasation can be identified in the infarcted placenta. Another CT finding of placental abruption is a retroplacental hematoma. The attenuation of a retroplacental hematoma often is similar to that of the subjacent myometrium, and careful attention to the interface

Teaching Point

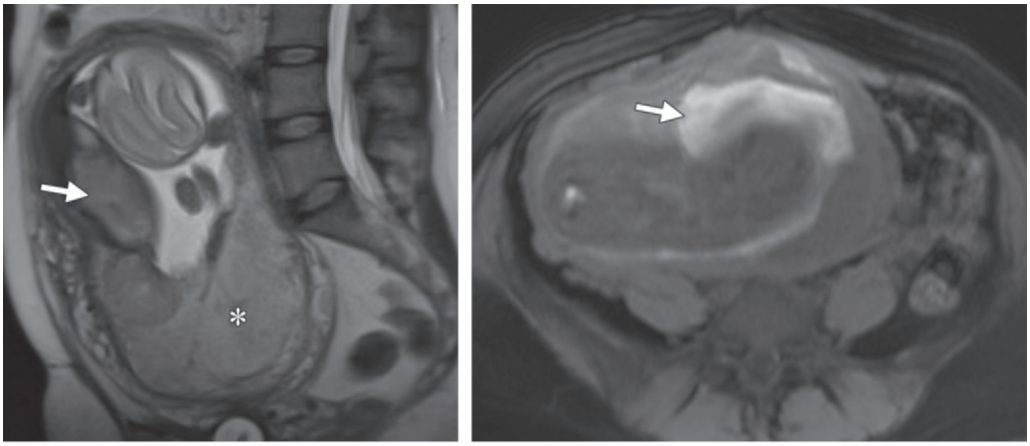
Figure 7. CT findings of placental abruption. **(a, b)** In a 30-week-pregnant patient who sustained pelvic fractures when a building facade collapsed onto her, axial **(a)** and sagittal reformatted **(b)** CT images show a nonenhancing placenta (arrows in **a**), a finding consistent with placental abruption. The small amount of hyperattenuating material seen in the placental tissue could represent blood products or minimally enhancing residual placental tissue. High-attenuating material seen inferiorly in the amniotic sac and uterine cavity (arrow in **b**) represents blood products. **(c)** Axial CT image in a different pregnant patient shows full-thickness areas of nonenhancement (arrows), a finding consistent with placental abruption. **(d)** Sagittal reformatted CT image in a pregnant patient in the third trimester shows that most of the placenta is nonenhancing (*). In addition, a lenticular high-attenuating collection is seen along the anterior inferior margin of the placenta (arrows), a finding consistent with a hematoma.

a. c. b. d.

between the placenta and the myometrium is recommended. In some cases, high-attenuation blood products can be detected in the amniotic fluid and are best identified in dependent portions of the amniotic sac (Fig 7).

Several CT findings can lead to a false-positive diagnosis of placental abruption. Myometrial contractions are a common mimic because these bulging areas of tissue appear hypoattenuating relative to the placenta. One method to distinguish myometrial contractions from placental abruption is to assess the interface between the areas of high and low attenuation, as myometrial contractions often form obtuse angles with the adjacent myometrium, while abruptions typically do not (47). Venous lakes, seen at imaging as areas of pooled maternal blood on the maternal side of the placenta, can also be misinterpreted as an abruption. Later in pregnancy, chorionic villous plate indentations can become more conspicuous and may simulate small infarcts. It is also important to recognize that small wedge-shaped placental infarcts may become apparent as the pregnancy matures

Figure 8. MR imaging findings of placental abruption. **(a)** Sagittal T2-weighted HASTE MR image shows a complex collection (arrow) with a fluid-blood level abutting the anterior aspect of the placenta (*). **(b)** Axial T1-weighted MR image shows fluid with high signal intensity (arrow), a finding consistent with hemorrhage. The patient underwent dilation and evacuation for chronic hemorrhage in a life-threatening pregnancy.



a. b.

and often have no clinical significance. Small subchorionic hemorrhages and preplacental hemorrhages can also be seen at various stages of pregnancy and should be reported but often have no clinical significance (37,47).

Although there are many mimics of placental abruption at CT, and the potential for false-positive findings exists, it is important to have a low threshold for suggesting the diagnosis because the costs of missing it are high. When a placental abruption is seen at imaging, it is important to include a description of the location (retroplacental or marginal) and the size of the perfusion abnormality relative to the overall placenta. CT findings can then be evaluated by the clinical team in conjunction with clinical symptoms (ie, uterine pain and vaginal bleeding) and data from external fetal monitoring (the most sensitive test for placental abruption) to confirm the diagnosis (6).

Placental abruption also can be detected at MR imaging. MR imaging of a pregnant patient typically is performed without gadolinium-based contrast material, and thus the key finding for placental abruption is a retroplacental or marginal hematoma. T1-weighted and diffusion-weighted MR imaging sequences are particularly helpful to identify the blood products of the hematoma, while T2-weighted MR imaging sequences can depict the hematoma and assist in determining its acuity. Although data regarding the use of MR imaging to detect abruptions is scarce, a small study of 19 patients reported that MR imaging was used to correctly identify placental abruption in all of the study patients, while US was able to depict placental abruption in only 10 of the 19 patients (50) (Fig 8).

Uterine Rupture and Penetrating Injury

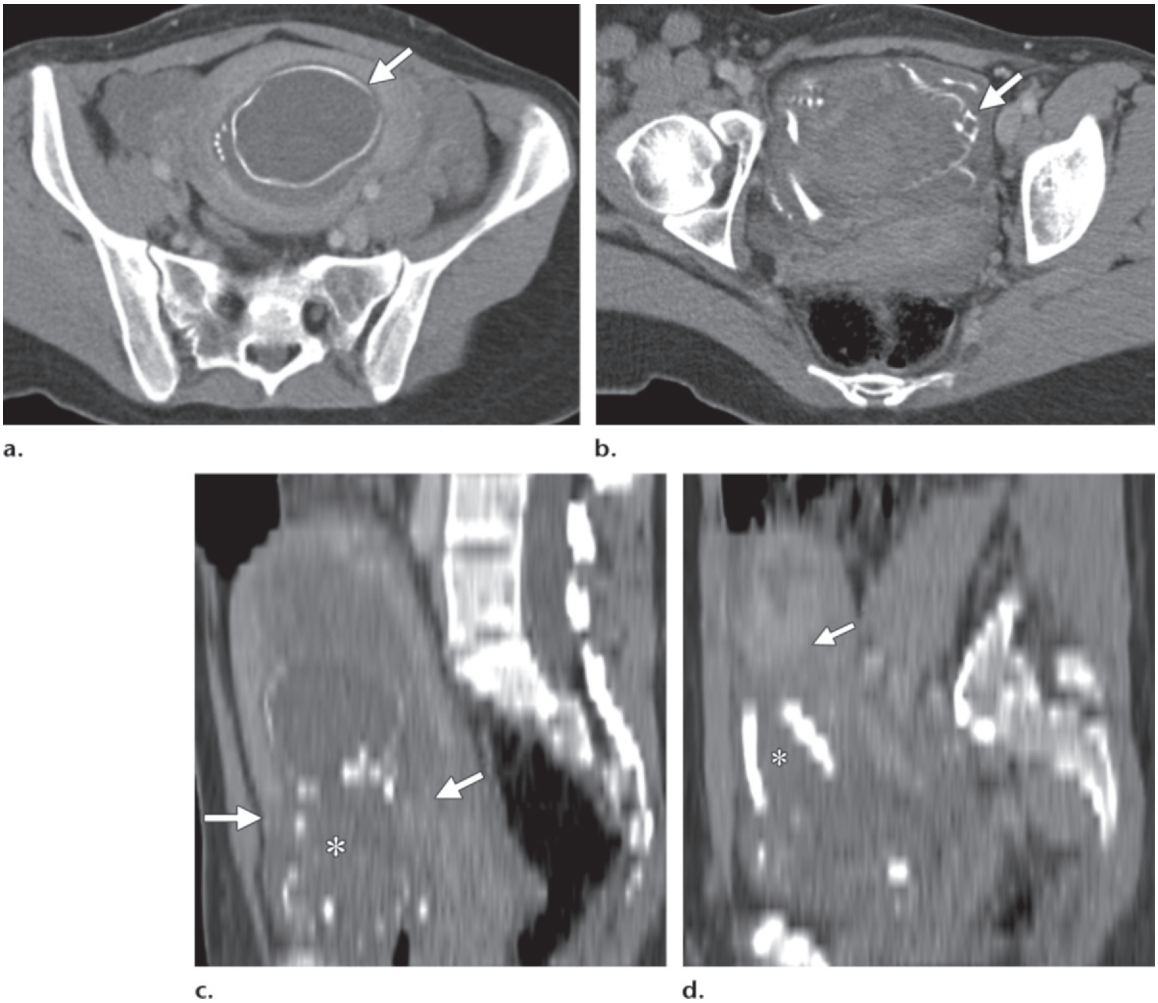
Uterine rupture and uterine lacerations are rare, occurring in less than 1% of pregnant trauma patients (51,52). However, given the nearly 100% fetal mortality and up to 10% maternal mortality (often due to other injuries) after uterine rupture, prompt diagnosis is essential (37). Patients with uterine injury can present with a wide spectrum of clinical findings, including pain, shock, and absent fetal heart tones, but the extent of uterine damage is difficult to predict at presentation and often is not discovered until imaging or surgery is performed (51). Diagnosis of uterine rupture at US is often difficult, but the diagnosis can be made using CT. In severe cases, a full-thickness defect can be seen in the uterine wall, with extrusion of the fetus into the abdomen (Fig 9). Hemoperitoneum will be seen at CT. More focal lacerations may be hard to detect at imaging but may be identified as focal defects or areas of hypoattenuation in the uterine wall (Fig 10). In the setting of penetrating trauma, careful attention should be paid to the path of the projectile, with careful note of gas or foreign bodies in or near the uterus (37,53) (Fig 11). In cases of penetrating injury, the radiologist should have a high index of suspicion for uterine injury, given that fetal injuries have been reported in up to 70% of cases of gunshot wounds to the abdomen, with fetal mortality rates of 40%–65% (1,51,54).

Teaching Point

Premature Rupture of Membranes and Spontaneous Abortion

Premature rupture of membranes and spontaneous abortion can occur after trauma. Premature rupture of membranes is largely a clinical

Figure 9. Uterine rupture in a 28-week-pregnant woman who was involved in a motor vehicle collision. US demonstrated absent fetal heart tones and free intraperitoneal fluid (not shown) but did not depict the full extent of injury. **(a, b)** Axial CT images show the fetal head in the uterine cavity (arrow in **a**), while the body is seen outside the uterus, uncovered by myometrium (arrow in **b**). **(c)** Sagittal reconstructed CT image shows the body of the fetus (*) extending beyond the margin of the uterus (arrows). **(d)** More lateral CT image shows fetal body parts (*) outside the uterus (arrow). The fetus was surgically removed, and the uterus was repaired.



diagnosis, but a decrease in the amount of amniotic fluid seen at either US or CT should be reported to draw attention to the finding in the event that it is not clinically suspected (55) (Fig 12). Diagnosis of spontaneous abortion in the first trimester involves a combination of clinical and sonographic features that are well described elsewhere in the literature (56). Features of spontaneous abortion can occasionally be detected at CT. At CT, low-lying products of conception, products of conception in the cervix, and blood in the cervix or vagina may be signs of an impending or ongoing spontaneous abortion (Fig 13).

Trauma and Ectopic Pregnancy

Ectopic pregnancy has an estimated incidence of 20 per 1000 pregnancies (57). Given this relatively high incidence, ectopic pregnancy will complicate the presentation of some pregnant trauma patients (Fig 14). In one series of 328 pregnant patients who had sustained blunt trauma, three patients were found to have a ruptured ectopic pregnancy at US examination. All three patients were diagnosed in the first trimester, and US showed isolated free fluid in the pelvis (15). Although not well studied at CT and MR imaging, the diagnosis of an ectopic pregnancy can be suggested at these examinations if there is an adnexal mass in a pregnant patient, hemoperitoneum, or an absence of intrauterine products of conception beyond the mid first trimester (58,59). Trauma to an ectopic pregnancy can manifest with confusing findings at imaging examination. Given that fetal parts may be dispersed in the abdomen, trauma to an ectopic pregnancy can have the appearance of uterine rupture. Although the actual diagnosis may not

Teaching Point

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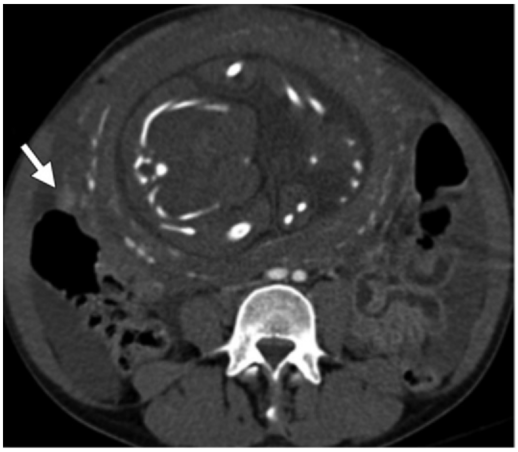
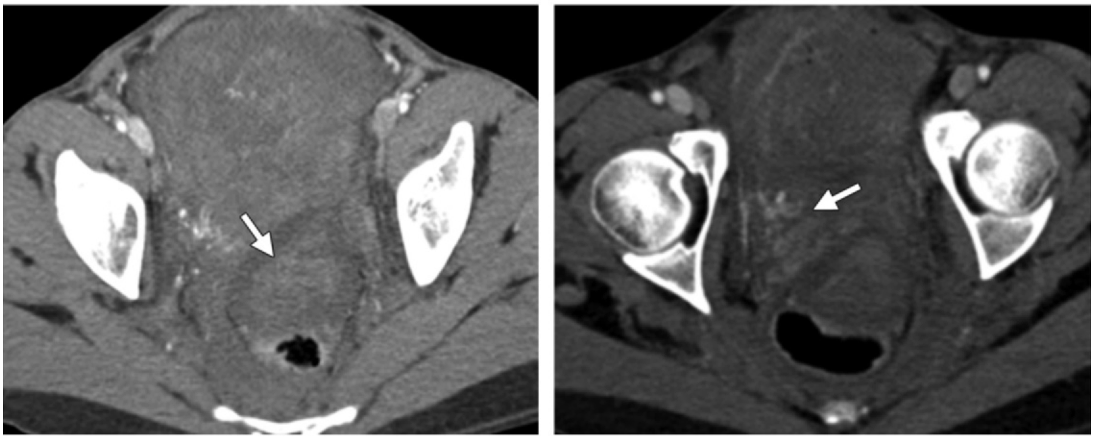


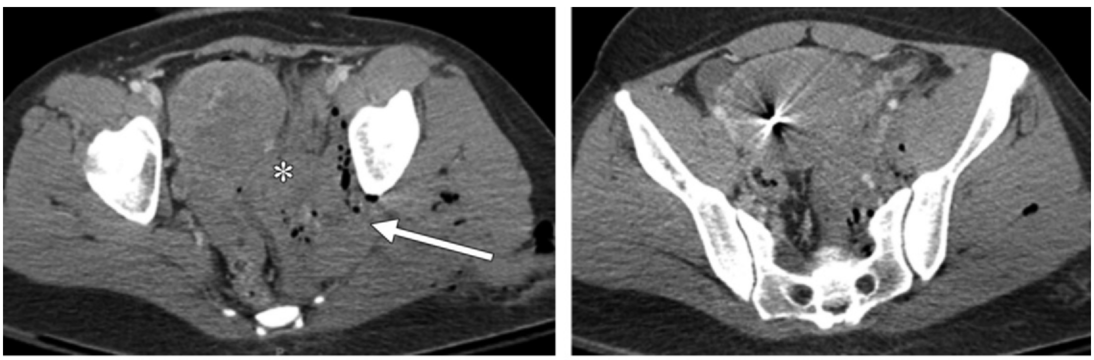
a.

Figure 10. Uterine injury after sexual assault in a 25–28-week-pregnant woman. US (not shown) demonstrated no fetal heart tones. CT showed free intraperitoneal fluid and gas in the cephalad portion of the abdomen (not shown). **(a)** Axial CT image shows free intravenous contrast material extravasated into the free fluid (arrow). The placenta is nonenhancing, a finding consistent with a large placental abruption or infarction. **(b)** Axial CT image shows a large hematoma in the pelvic cul-de-sac (arrow). **(c)** Axial CT image shows high-attenuating material (representing extravasating contrast material) at the junction of the cervix and vagina (arrow). At laparotomy, a right-sided avulsion of the uterus and cervix from the vaginal apex and a right uterine artery avulsion were found.



b. c.

Figure 11. Uterine lacerations from penetrating trauma in a pregnant woman who was shot in the left buttock during the first trimester. **(a)** Axial CT image shows the bullet tract (arrow) and a large hematoma in the left extraperitoneal pelvis along the tract (*). **(b)** Axial CT image shows a bullet fragment lodged in the uterus. Free intraperitoneal gas was seen more cranially in the abdomen (not shown). The bullet's trajectory placed the sigmoid colon, bladder, ureter, and pelvic vessels at risk, but possible injuries to these structures were difficult to detect at imaging. At surgery, the uterus was evacuated and repaired, a sigmoid colon injury was found and repaired, a left ureteral injury was found and a stent was placed, and a bleeding branch of the left internal iliac artery was ligated.

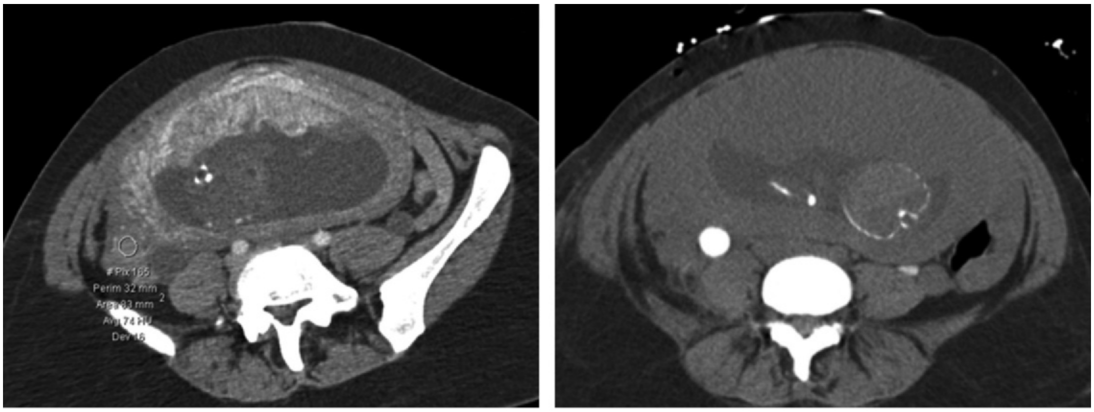


a. b.

be made until surgery, a constellation of imaging findings that include free-floating fetal parts, an empty uterus, and an adnexal mass or cystic structure suggest a ruptured ectopic pregnancy in the setting of trauma (Fig 15).

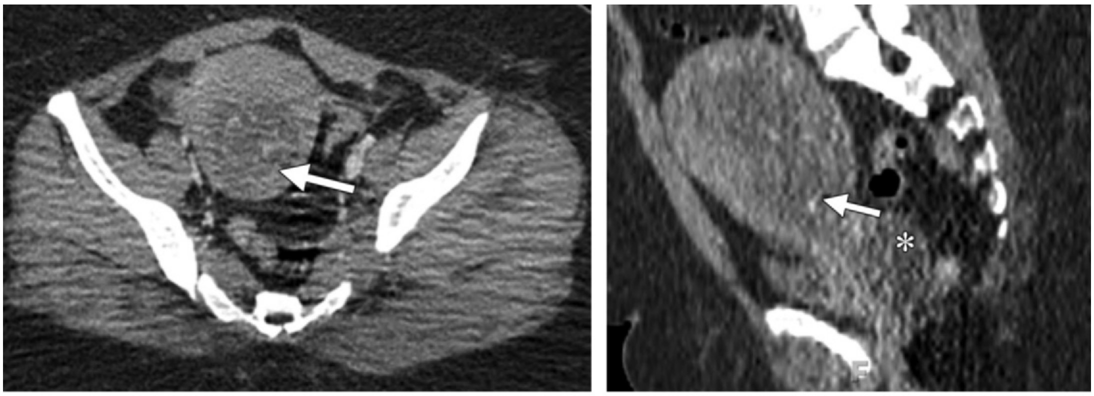
Value of a Negative Imaging Examination

Even if no injuries are found, a negative imaging examination can play a pivotal role in directing appropriate nonsurgical management of a pregnant



a. b.

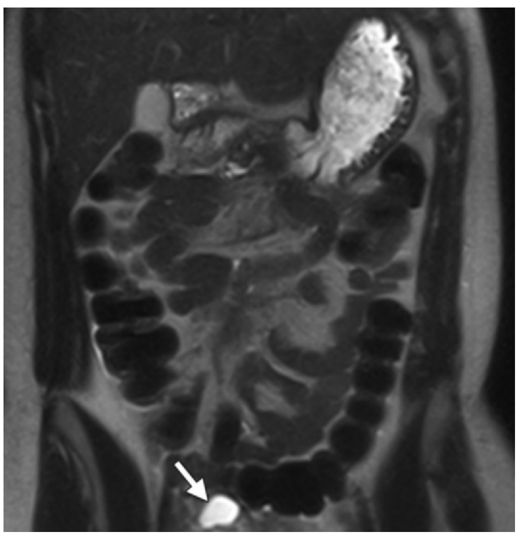
Figure 12. **(a)** Axial CT image in a 21-week-pregnant woman who was involved in a motor vehicle collision shows a normal-appearing placenta and a normal amount of amniotic fluid. Hemoperitoneum from other injuries is seen (circle). **(b)** Follow-up non–contrast-enhanced CT image obtained 1 day after **a** shows a substantial decrease in the amount of amniotic fluid, a finding consistent with premature rupture of membranes, which was confirmed at clinical examination.



a. b.

Figure 13. Incomplete spontaneous abortion in a 14-week-pregnant patient who was involved in a motor vehicle collision. The patient had multiple orthopedic injuries, episodes of hypotension, and vaginal bleeding. No intra-abdominal injuries were found at CT examination, but the axial and sagittal CT images in **a** and **b** show products of conception low in the uterine cavity (arrow) and fluid distending the vagina (* in **b**), findings consistent with an incomplete spontaneous abortion. The placenta was evacuated the next day because it did not completely pass on its own.

Figure 14. This 4-week-pregnant patient had multiple orthopedic injuries. As the patient was stable but did have some mild abdominal pain, an MR imaging examination was performed to rule out visceral injury (no injury was seen). Coronal T2-weighted HASTE MR image shows a cystic structure in the right adnexa (arrow), which was felt to represent a corpus luteum cyst. No pregnancy was seen in the uterus (not shown). A US study performed 1 day later (not shown) could not identify an intrauterine pregnancy and suggested that the structure in the right adnexa was an ectopic pregnancy. A right tubal ectopic pregnancy was confirmed at surgery and removed.



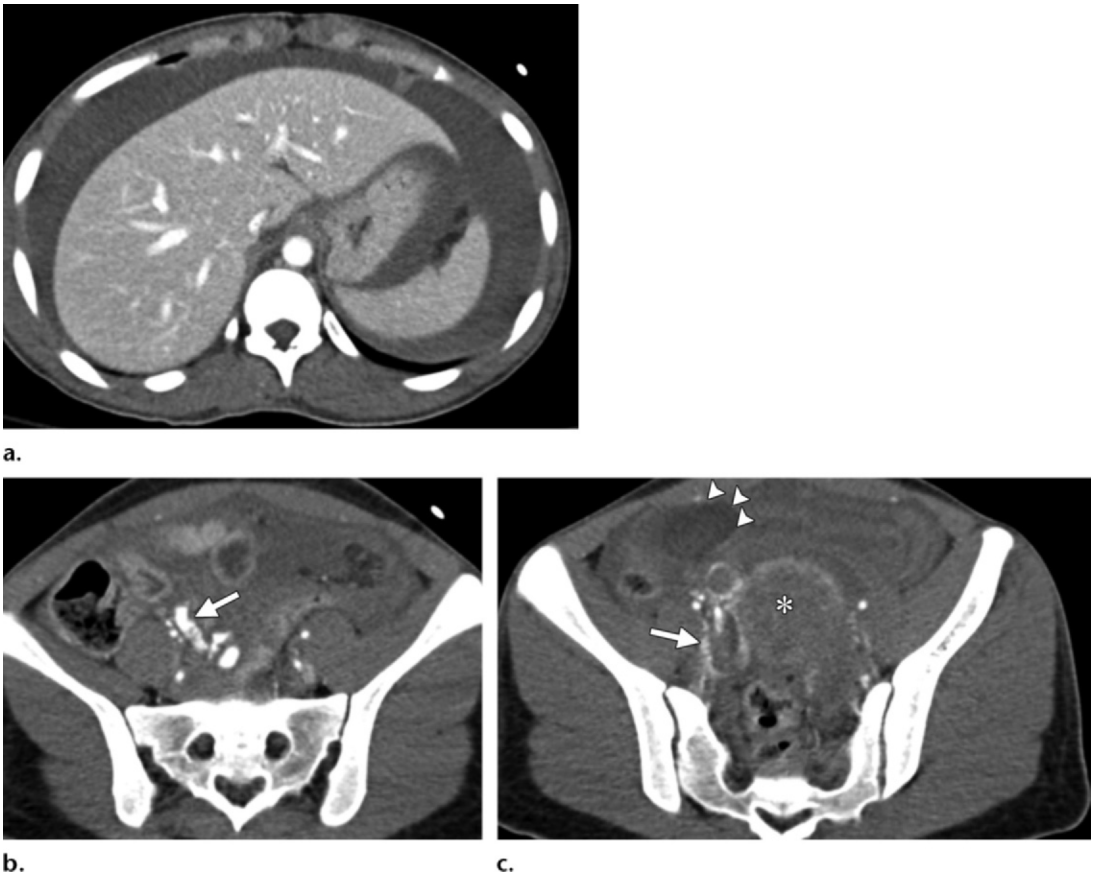


Figure 15. Ruptured ectopic pregnancy in a 10-week-pregnant patient who was involved in a motor vehicle collision. Although the patient initially was stable, her condition worsened, and she complained of severe abdominal pain. **(a)** Axial CT image shows large-volume hemoperitoneum. **(b)** Axial CT image shows high-attenuation material (arrow) near the right ovary, a finding consistent with active extravasation of contrast material. **(c)** Axial CT image shows fetal parts (arrow) outside the uterus (*). A fluid-filled structure near the right adnexa (arrowheads) is suggestive of a gestational sac. Although the finding of fetal parts outside the uterus suggests uterine rupture, the otherwise normal-appearing uterus and the suggestion of a gestational sac in the right adnexa raise the question of a ruptured ectopic pregnancy. A ruptured right tubal ectopic pregnancy was confirmed at surgery, and products of conception were found floating freely in the abdomen.

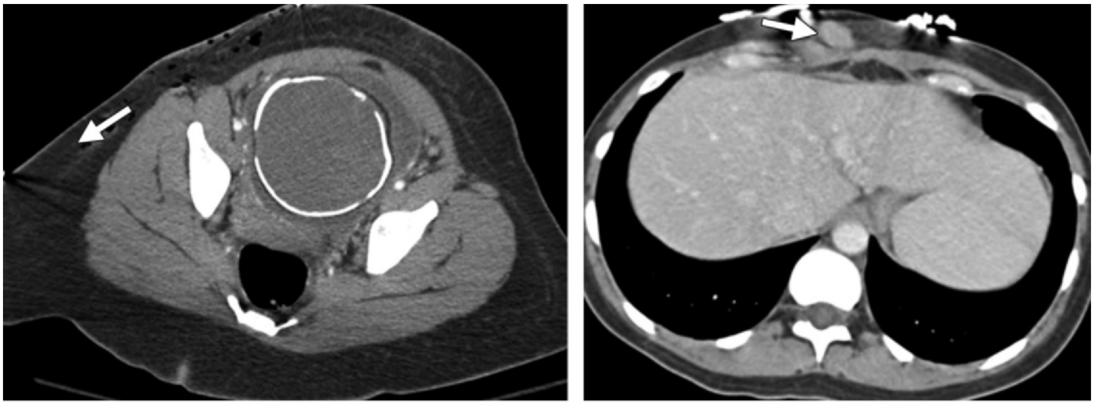
trauma patient. This is particularly true for women with penetrating injuries, where CT may demonstrate only superficial injuries and an absence of deeper injuries that would require surgery. Nonsurgical management is beneficial for pregnant trauma patients because nonobstetric laparotomies increase the risk for preterm labor (7) (Fig 16).

Conclusion

Evaluation of the pregnant trauma patient is challenging for both clinicians and radiologists. To promote the best outcome for the mother and fetus, maternal injuries must be promptly diagnosed. From an imaging standpoint, the workup of the pregnant trauma patient should proceed as for any patient, using conventional radiography, CT, and MR imaging as needed. When modalities with ionizing radiation are used, the radiation doses should be kept as low as reasonably achievable, bearing in mind that the fetal dose for nearly all diagnostic imaging examinations is less than the threshold of 50 mGy, below which there is no association with increased fetal anomalies or pregnancy loss. During imaging interpretation, it is essential that maternal injuries are accurately diagnosed. These injuries include the same spectrum of injuries seen in any trauma patient as well as pregnancy-specific injuries, including placental abruption and uterine rupture. Ultimately, a precise description of injuries in the pregnant trauma patient by the radiologist will best help guide clinical management.

References

1. Mattox KL, Goetzl L. Trauma in pregnancy. Crit Care Med 2005;33(suppl 10):S385–S389.
2. Towery R, English TP, Wisner D. Evaluation of pregnant women after blunt injury. J Trauma 1993;35(5):731–735; discussion 735–736.



a. b.

Figure 16. **(a)** Axial CT image in a pregnant patient in the third trimester who presented with a gunshot wound to the right abdomen shows the bullet tract (arrow) in the right anterior subcutaneous tissues, with no underlying fascial penetration. **(b)** Axial CT image in a 13-week-pregnant patient who was stabbed in the upper abdomen shows a hematoma and stranding in the abdominal wall and subjacent fat (arrow) but no evidence of liver or intraperitoneal injury. Both patients were treated nonsurgically and did well.

3. Connolly AM, Katz VL, Bash KL, McMahon MJ, Hansen WF. Trauma and pregnancy. Am J Perinatol 1997;14(6):331–336.
4. Pearlman MD, Tintinalli JE, Lorenz RP. Blunt trauma during pregnancy. N Engl J Med 1990;323(23):1609–1613.
5. Ueland K, Hansen JM. Maternal cardiovascular dynamics. II. Posture and uterine contractions. Am J Obstet Gynecol 1969;103(1):1–7.
6. Sadro C, Bittle M, O'Connell K. Imaging the pregnant trauma patient. Ultrasound Clin 2011;6(1): 97–113.
7. Visser BC, Glasgow RE, Mulvihill KK, Mulvihill SJ. Safety and timing of nonobstetric abdominal surgery in pregnancy. Dig Surg 2001;18(5):409–417.
8. Puri A, Khadem P, Ahmed S, Yadav P, Al-Dulaimy K. Imaging of trauma in a pregnant patient. Semin Ultrasound CT MR 2012;33(1):37–45.
9. Rose JS. Ultrasound in abdominal trauma. Emerg Med Clin North Am 2004;22(3):581–599, vii.
10. Branney SW, Wolfe RE, Moore EE, et al. Quantitative sensitivity of ultrasound in detecting free intraperitoneal fluid. J Trauma 1995;39(2):375–380.
11. Shackford SR, Rogers FB, Osler TM, Trabulsy ME, Clauss DW, Vane DW. Focused abdominal sonogram for trauma: the learning curve of nonradiologist clinicians in detecting hemoperitoneum. J Trauma 1999;46(4):553–562; discussion 562–564.
12. Richards JR, McGahan JP, Jones CD, Zhan S, Gerscovich EO. Ultrasound detection of blunt splenic injury. Injury 2001;32(2):95–103.
13. Richards JR, McGahan JP, Pali MJ, Bohnen PA. Sonographic detection of blunt hepatic trauma: hemoperitoneum and parenchymal patterns of injury. J Trauma 1999;47(6):1092–1097.
14. Brown MA, Casola G, Sirlin CB, Hoyt DB. Importance of evaluating organ parenchyma during screening abdominal ultrasonography after blunt trauma. J Ultrasound Med 2001;20(6):577–583; quiz 585.
15. Richards JR, Ormsby EL, Romo MV, Gillen MA, McGahan JP. Blunt abdominal injury in the pregnant patient: detection with US. Radiology 2004; 233(2):463–470.
16. Goodwin H, Holmes JF, Wisner DH. Abdominal ultrasound examination in pregnant blunt trauma patients. J Trauma 2001;50(4):689–693; discussion 694.
17. Brown MA, Sirlin CB, Farahmand N, Hoyt DB, Casola G. Screening sonography in pregnant patients with blunt abdominal trauma. J Ultrasound Med 2005;24(2):175–181; quiz 183–184.
18. American College of Radiology and the Society for Pediatric Radiology. ACR-SPR practice guideline for imaging pregnant or potentially pregnant adolescents and women with ionizing radiation. http://www.acr.org/~/media/9e2ed55531fc4b4fa53ef3b6d3b25df8.pdf. Published 2013. Accessed January 16, 2013.
19. American College of Obstetrics and Gynecology Committee on Obstetric Practice. ACOG committee opinion: guidelines for diagnostic imaging during pregnancy. Obstet Gynecol 2004;104(3):647–651.
20. National Council on Radiation Protection and Measurements. Medical radiation exposure of pregnant and potentially pregnant women. Report no. 54. Bethesda, Md: National Council on Radiation Protection and Measurements, 1977.
21. McCollough CH, Schueler BA, Atwell TD, et al. Radiation exposure and pregnancy: when should we be concerned? RadioGraphics 2007;27(4):909–917; discussion 917–918.
22. Osei EK, Faulkner K. Fetal doses from radiological examinations. Br J Radiol 1999;72(860): 773–780.
23. Chen MM, Coakley FV, Kaimal A, Laros RK Jr. Guidelines for computed tomography and magnetic resonance imaging use during pregnancy and lactation. Obstet Gynecol 2008;112(2 Pt 1):333–340.
24. Nguyen CP, Goodman LH. Fetal risk in diagnostic radiology. Semin Ultrasound CT MR 2012;33(1):4–10.
25. Bentur Y, Horlatsch N, Koren G. Exposure to ionizing radiation during pregnancy: perception of teratogenic risk and outcome. Teratology 1991;43(2):109–112.
26. Bourjeily G, Chalhoub M, Phornphutkul C, Alleyne TC, Woodfield CA, Chen KK. Neonatal thyroid function: effect of a single exposure to iodinated contrast medium in utero. Radiology 2010;256(3): 744–750.

27. Atwell TD, Lteif AN, Brown DL, McCann M, Townsend JE, Leroy AJ. Neonatal thyroid function after administration of IV iodinated contrast agent to 21 pregnant patients. AJR Am J Roentgenol 2008;191(1):268–271.
28. Kochi MH, Kaloudis EV, Ahmed W, Moore WH. Effect of in utero exposure of iodinated intravenous contrast on neonatal thyroid function. J Comput Assist Tomogr 2012;36(2):165–169.
29. ACR Manual on Contrast Media. American College of Radiology Web site. http://www.acr.org/~/media/ACR/Documents/PDF/QualitySafety/Resources/Contrast%20Manual/2013_Contrast_Media.pdf. Published 2013. Accessed January 16, 2013.
30. Expert Panel on MR Safety, Kanal EK, Barkovich AJ, et al. ACR guidance document on MR safe practices: 2013. J Magn Reson Imaging 2013;37(3):501–530.
31. Patel SJ, Reede DL, Katz DS, Subramaniam R, Amorosa JK. Imaging the pregnant patient for nonobstetric conditions: algorithms and radiation dose considerations. RadioGraphics 2007;27(6):1705–1722.
32. Shellock FG, Crues JV. MR procedures: biologic effects, safety, and patient care. Radiology 2004;232(3):635–652.
33. De Wilde JP, Rivers AW, Price DL. A review of the current use of magnetic resonance imaging in pregnancy and safety implications for the fetus. Prog Biophys Mol Biol 2005;87(2–3):335–353.
34. Sundgren PC, Leander P. Is administration of gadolinium-based contrast media to pregnant women and small children justified? J Magn Reson Imaging 2011;34(4):750–757.
35. Goldman SM, Wagner LK. Radiologic ABCs of maternal and fetal survival after trauma: when minutes may count. RadioGraphics 1999;19(5):1349–1357.
36. Pearlman MD, Klinich KD, Schneider LW, Rupp J, Moss S, Ashton-Miller J. A comprehensive program to improve safety for pregnant women and fetuses in motor vehicle crashes: a preliminary report. Am J Obstet Gynecol 2000;182(6):1554–1564.
37. Sadro C, Bernstein M, Kanal K. Imaging of trauma. II. Abdominal trauma and pregnancy: a radiologist's guide to doing what is best for the mother and baby. AJR Am J Roentgenol 2012;199(6):1207–1219.
38. Shah KH, Simons RK, Holbrook T, Fortlage D, Winchell RJ, Hoyt DB. Trauma in pregnancy: maternal and fetal outcomes. J Trauma 1998;45(1):83–86.
39. Brown S, Mozurkewich E. Trauma during pregnancy. Obstet Gynecol Clin North Am 2013;40(1):47–57.
40. Leggon RE, Wood GC, Indeck MC. Pelvic fractures in pregnancy: factors influencing maternal and fetal outcomes. J Trauma 2002;53(4):796–804.
41. Ananth CV, Berkowitz GS, Savitz DA, Lapinski RH. Placental abruption and adverse perinatal outcomes. JAMA 1999;282(17):1646–1651.
42. Knab DR. Abruptio placentae: an assessment of the time and method of delivery. Obstet Gynecol 1978;52(5):625–629.
43. Naeye RL. Abruptio placentae and placenta previa: frequency, perinatal mortality, and cigarette smoking. Obstet Gynecol 1980;55(6):701–704.
44. Rasmussen S, Irgens LM, Bergsjo P, Dalaker K. Perinatal mortality and case fatality after placental abruption in Norway, 1967–1991. Acta Obstet Gynecol Scand 1996;75(3):229–234.
45. Glantz C, Purnell L. Clinical utility of sonography in the diagnosis and treatment of placental abruption. J Ultrasound Med 2002;21(8):837–840.
46. Nyberg DA, Cyr DR, Mack LA, Wilson DA, Shuman WP. Sonographic spectrum of placental abruption. AJR Am J Roentgenol 1987;148(1):161–164.
47. Wei SH, Helmy M, Cohen AJ. CT evaluation of placental abruption in pregnant trauma patients. Emerg Radiol 2009;16(5):365–373.
48. Manriquez M, Srinivas G, Bollepalli S, Britt L, Drachman D. Is computed tomography a reliable diagnostic modality in detecting placental injuries in the setting of acute trauma? Am J Obstet Gynecol 2010;202(6):e1–e5. doi:10.1016/j.ajog.2010.01.027. Published March 12, 2010. Accessed April 1, 2013.
49. Lowdermilk C, Gavant ML, Qaisi W, West OC, Goldman SM. Screening helical CT for evaluation of blunt traumatic injury in the pregnant patient. RadioGraphics 1999;19(Spec No):S243–S255; discussion S256–S258.
50. Masselli G, Brunelli R, Di Tola M, Anceschi M, Gualdi G. MR imaging in the evaluation of placental abruption: correlation with sonographic findings. Radiology 2011;259(1):222–230.
51. Brown HL. Trauma in pregnancy. Obstet Gynecol 2009;114(1):147–160.
52. El-Kady D, Gilbert WM, Anderson J, Danielsen B, Towner D, Smith LH. Trauma during pregnancy: an analysis of maternal and fetal outcomes in a large population. Am J Obstet Gynecol 2004;190(6):1661–1668.
53. Dash N, Lupetin AR. Uterine rupture secondary to trauma: CT findings. J Comput Assist Tomogr 1991;15(2):329–331.
54. Sandy EA 2nd, Koerner M. Self-inflicted gunshot wound to the pregnant abdomen: report of a case and review of the literature. Am J Perinatol 1989;6(1):30–31.
55. Caughey AB, Robinson JN, Norwitz ER. Contemporary diagnosis and management of preterm premature rupture of membranes. Rev Obstet Gynecol 2008;1(1):11–22.
56. Dighe M, Cuevas C, Moshiri M, Dubinsky T, Dogra V. Sonography in first trimester bleeding. J Clin Ultrasound 2008;36(6):352–366.
57. Centers for Disease Control and Prevention. Ectopic pregnancy: United States, 1990–1992. MMWR Morb Mortal Wkly Rep 1995;44(3):46–48.
58. Pham H, Lin EC. Adnexal ring of ectopic pregnancy detected by contrast-enhanced CT. Abdom Imaging 2007;32(1):56–58.
59. Shin DS, Poder L, Courtier J, Naeger DM, Westphalen AC, Coakley FV. CT and MRI of early intrauterine pregnancy. AJR Am J Roentgenol 2011;196(2):325–330.

RadioGraphics

Imaging of Trauma in the Pregnant Patient

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Page 749
The first goal of the medical team caring for the pregnant trauma patient is to stabilize the mother, keeping in mind that maternal demise will almost always lead to fetal demise.

Page 749
As described in the 2008 American College of Radiology practice guidelines for imaging pregnant or potentially pregnant patients and supported by the American College of Obstetricians and Gynecologists and the National Council on Radiation Protection and Measurements, fetal radiation doses of less than 50 mGy are not associated with increased fetal anomalies or fetal loss throughout pregnancy. This concept is important because the radiation doses of essentially all diagnostic imaging examinations using ionizing radiation that would be used in a trauma evaluation should be well below this threshold.

Page 755
Placental abruption is best characterized on CT images as a contiguous retroplacental or full-thickness area of decreased enhancement that forms acute angles with the myometrium.

Page 757
Diagnosis of uterine rupture at US is often difficult, but the diagnosis can be made using CT. In severe cases, a full-thickness defect can be seen in the uterine wall, with extrusion of the fetus into the abdomen.

Pages 758–759
Although the actual diagnosis may not be made until surgery, a constellation of imaging findings that include free-floating fetal parts, an empty uterus, and an adnexal mass or cystic structure suggest a ruptured ectopic pregnancy in the setting of trauma.