OBJECTIVE. The pregnant trauma patient requires imaging tests to diagnose maternal injuries and diagnostic tests to evaluate the viability of her pregnancy. This article will discuss abdominal trauma in pregnancy and the specific role of diagnostic imaging. Radiation concerns in pregnancy will be addressed.

CONCLUSION. Trauma is the leading cause of nonobstetric maternal mortality and a significant cause of fetal loss. Both major and minor trauma result in an increased risk of fetal loss. In major trauma, when there is concern for maternal injury, CT is the mainstay of imaging. The risks of radiation to the pregnancy are small compared with the risk of missed or delayed diagnosis of trauma. In minor trauma, when there is no concern for maternal injury but there is concern about the pregnancy, ultrasound is performed but is insensitive in diagnosing placental abruption. External fetal monitoring is used to dictate patient care.

Trauma is the leading cause of nonobstetric maternal mortality affecting up to 7% of pregnancies [1–13] and is a significant cause of fetal loss [2–4]. Approximately 2% of level-1 trauma patients have a positive pregnancy test [12]. Pregnant trauma patients are more likely to sustain serious abdominal injury than nonpregnant trauma patients [5], and most obstetric complications of trauma occur in the third trimester [13]. Causes of trauma in pregnancy include motor vehicle crashes (49%), falls (25%), assaults and domestic violence (18%), and gunshot injuries (4%) [14] (Table 1). The incidence of domestic violence sharply increases in pregnancy [5, 6, 11–13, 15].

Both major and minor trauma result in an increased risk of pregnancy loss [5–12]. Patients with a higher injury severity score (ISS) are at greater risk of pregnancy loss. With an ISS > 25 [16], there is a 50% risk of fetal death [7]. However, fetal death may be seen with an ISS as low as 1 or 2 [10, 11]. Overall, the fetal loss rate in trauma is reported to be from 1% to 34% [5–12]. With penetrating abdominal injury, the fetal loss rate reaches 73% [17, 18].

Maternal death almost always results in fetal death [12]. Although there are reports of late third trimester pregnancies delivered by emergency cesarean section despite lethal maternal injuries, such cases are rare. The best chance for fetal survival is maternal survival, and all efforts are made to save the mother. When the mother survives, the most common cause of pregnancy loss is placental abruption [5, 7, 15].

The purposes of this article are to briefly describe the clinical approach to managing the pregnant trauma patient, discuss the risks and benefits of imaging the pregnant trauma patient with modalities using ionizing radiation, show the normal CT appearance of the gravid uterus and the physiologic changes that occur during pregnancy, show traumatic conditions that occur in pregnancy and those traumatic conditions that place the fetus at most risk, and discuss strategies for prevention of trauma in pregnancy.

Clinical Management

The clinical management of the pregnant trauma patient starts with maternal stabilization beginning with the ABCs of airway, breathing, and circulation. Caring for the pregnant trauma patient is challenging because of the altered physiology of pregnancy and because there are two lives at risk. A multidisciplinary approach that includes emergency medicine, trauma surgery, obstetrics and gynecology, radiology, and nursing is crucial in these patients.

After 20 weeks of gestation, the pregnant patient should be placed in the left lateral decubitus position to prevent compression of the inferior vena cava (IVC) by the gravid uterus.
Evaluation of the fetus only begins after maternal stabilization [20]. A fetus can survive delivery after 24–26 weeks of gestation or 500 g [20]. Continuous external fetal monitoring with devices that measure fetal heart rate and uterine tone and contractility is performed in pregnant trauma patients beyond 24 weeks of gestation for at least 4 hours and is the most sensitive test to diagnose placental abruption, preterm labor, and fetal distress [20]. Signs of placental abruption and fetal distress on external fetal monitoring include increased uterine tone and contractility and worrisome fetal heart tones, including fetal bradycardia and late decelerations (Fig. 1). Such signs beyond 24 weeks prompt emergency cesarean delivery [3].

### Imaging

In major trauma, the pregnant trauma patient is imaged with radiography, CT, and angiography as necessary. Imaging begins with portable radiography of the chest and, when clinically indicated, the pelvis. Focused abdominal sonography for trauma (FAST) is performed in the trauma bay to identify free intraperitoneal fluid and pericardial fluid. Ultrasound also enables determination of gestational age, fetal heart rate, amniotic fluid volume, and placental position. Unfortunately, although free of ionizing radiation, ultrasound is of limited utility in detecting maternal injuries, including active arterial bleeding.

Radiography, CT, and angiography produce ionizing radiation. In major trauma, the risks of radiation to the pregnancy are small compared with the risk of missed or delayed diagnosis of maternal injury.

CT is the proven modality for the evaluation of trauma patients and remains the test of choice for injured pregnant patients. However, efforts are made to eliminate unnecessary scans, reduce overlap of body sections, and avoid multiple passes where possible. It is important to generate a diagnostic test, and for that reason extreme low-dose protocols are not used.

At Harborview Medical Center, diagnostic abdominopelvic CT is performed in the portal venous phase after a 70-second delay. The typical contrast regimen for patients weighing between 122–200 lbs (55.3–90.7 kg) is 150 mL delivered at 3.5 mL/s. For a 16-MDCT scanner, we use a section thickness of 2.5 mm; pitch, 1.375; noise index, 16.1; and 120 kV. The tube current–time product depends on patient size and is approximately 240 mAs (effective mAs, 175). The radiologist checks the scan while the patient is on the CT table. Delayed scans at 5–10 minutes are performed selectively to evaluate for collecting system rupture in the setting of renal trauma or to evaluate for active bleeding into hematomas when the diagnosis is in doubt on the initial scan. Delayed scans are focused on the area of interest and are performed with a lower dose than the initial scan, in which the noise index is increased to 22.1 and, in the case of renal trauma, the kilovoltage is decreased to 100. CT cystography is performed in at-risk patients to evaluate for bladder rupture if there is gross hematuria and stranding or fluid around the bladder or if there is microscopic hematuria in the setting of a pelvic fracture or penetrating trauma. CT cystography is performed with a very-low-dose technique with the noise index increased to 32.6. CT scans of the spine and bony pelvis are reconstructed from the original dataset. This is the same protocol used in nonpregnant trauma patients at Harborview Medical Center.

The decision to perform abdominopelvic CT in a pregnant trauma patient to diagnose serious abdominal injury typically encountered in high-energy trauma, such as motor vehicle crashes, is at the discretion of the treating physician. Severe abdominal injury is more common in pregnant trauma patients than in nonpregnant trauma patients [5]. In a retrospective study of two level I trauma centers performed by Lowdermilk et al. [12], 7.9% of pregnant trauma patients were evaluated with CT and 50% of those patients presented in the third trimester.

IV iodinated CT contrast material is a Food and Drug Administration (FDA) category B agent with no known adverse effects to the pregnancy and is administered as necessary [22, 23]. Specifically, it does not alter neonatal thyroid function [24, 25]. MRI is safe in pregnancy at 1.5 T, although it is rarely performed in acute trauma because it removes the patient from emergency personnel, is a difficult setting to monitor the patient, and is time intensive. Unlike CT contrast material, however, gadolinium is an FDA category C agent with known teratogenic effects in animals and is contraindicated in pregnancy [22, 23].

Angiography is performed to diagnose and treat active bleeding in critically injured pregnant trauma patients who do not meet the criteria for emergency surgery. Efforts are made to reduce the dose from fluoroscopy delivered to the gravid uterus. If the patient is stable enough to first undergo CT, the interventional radiologist reviews the CT scan to determine the most likely site of bleeding to minimize the number of vessels that need to be injected. The interventional radiologist can use strategies to keep the fetal dose to a minimum, such as minimizing fluoroscopic time, decreasing the fluoroscopy frame rate, minimizing the number of spot films by using the last image hold feature when applicable, tailoring the digital subtraction angiography (DSA) frame rate and total number of frames in a sequence to the anatomic area and blood flow rate being imaged, and using image magnification only as necessary. The patient is imaged semisupine and posteroanterior with the x-ray tube situated posterior and the image intensifier anterior and as close to the patient as possible with optimal collimation. If the site of bleeding is not the pelvis, a lead shield may be placed posterior to the gravid uterus. Arm or neck access may be considered in these patients [26, 27].

Informed consent is recommended when radiography, CT, or fluoroscopic procedures are performed through the gravid uterus and when IV iodinated contrast material is administered to pregnant patients [23, 28]. However, in seriously injured patients, the medical emergency does not permit the full consent process. In these cases, standard institutional procedure should be followed to document the necessity of the procedure [12, 26, 27].
Although the initial assessment of the pregnant trauma patient is performed with CT, follow-up imaging of abdominal or pelvic trauma may be performed with ultrasound or unenhanced MRI to reduce the cumulative dose from multiple CT examinations. For example, certain hematomas may be followed with ultrasound, and pancreatic duct injuries may be evaluated with MRCP [29, 30].

**Radiation Risks and Pregnancy**

Ionizing radiation has potentially harmful effects on living tissue. The fetus is more sensitive to the harmful effects of ionizing radiation than children and adults. Fetal risks from ionizing radiation include small head size, mental retardation, organ malformations, cancer, and death [31]. This has led to reluctance among physicians to perform radiography and CT in pregnancy.

Background radiation experienced by the fetus over the 9 months of gestation is approximately 1 mGy [32]. Fetal radiation exposures of less than 1 mGy are not significant and do not require counseling [32]. Table 2 lists fetal doses for common radiographic examinations and Table 3 lists fetal doses for common CT examinations. When the fetus is not in the FOV, the radiation dose is negligible. When the fetus is directly irradiated for pelvic radiography, the dose is approximately 1–3 mGy [33].

The fetal dose from a typical CT of the abdomen and pelvis is 25 mGy [33]. A recent study that used Monte Carlo simulations of pregnant patient models representing a range of gestational ages and maternal sizes found that the fetal dose from CT did not depend on the gestational age of the pregnancy but rather on the maternal abdominal perimeter and the depth of the fetus from the anterior maternal skin surface. A larger maternal perimeter and a greater depth of the fetus from the anterior maternal skin surface resulted in a smaller fetal dose. The average fetal dose in that study was 24 mGy for a 16-MDCT scanner using typical scanning parameters and ranged from 16 to 31 mGy depending on maternal size [34]. The fetal dose will vary depending on scanning parameters. With modern CT scanners that use automated exposure control, the fetal dose may be reduced further and was reported to be as low as 13 mGy for CT of the abdomen and pelvis by Wieseler et al. [35].

The fetal dose from fluoroscopy over the gravid uterus for pelvic angiography is 20–100 mGy/min depending on maternal thickness and the number of vessels injected [36].

In 1977, the National Council of Radiation Protection and Measurements issued the following policy statement with regard to radiation and pregnancy [37]: “The risk [of abnormality] is considered to be negligible at 50 mGy or less, . . .” A similar conclusion was drawn by the American College of Obstetricians and Gynecologists in 2004 in the following statement [38]: “Women should be counseled that x-ray exposure from a single diagnostic procedure does not result in harmful fetal effects. Specifically, exposure to less than 5 rad [50 mGy] has not been associated with an increase in fetal anomalies or pregnancy loss.”

The risks of ionizing radiation to the fetus depend on the dose and the gestational age at exposure (Table 4). In the first 2 weeks after conception, the main risk is spontaneous abortion. The effect is all or none and is only observed at doses greater than 50–100 mGy [39]. Teratogenic effects, such as small head size, mental retardation, and organ malformations, are only observed at high doses (typically greater than 100 mGy) between 2 and 15 weeks after conception. This is the period of organogenesis and rapid neuronal development and migration [39]. (Gestational age is used clinically and equals the weeks after conception plus 2 weeks.)

The risk of childhood cancer from in utero exposure to ionizing radiation exists throughout pregnancy. Several reports place the background risk of childhood cancer mortality at 0.14%. An in utero exposure of 10 mGy increases this risk by 0.06% [31, 40, 41], which translates to 1 excess cancer death per 1700 [32]. According to the American College of Radiology Practice Guideline for Imaging Pregnant or Potentially Pregnant Adolescents and Women With Ionizing Radiation, exposure of the newborn child to 10 mGy of ionizing radiation increases the absolute lifetime risk of developing cancer by 0.4% and exposure to 50 mGy increases this risk by 2% [28]. It is assumed that this also reflects the potential risk to the conceptus in utero for the second and third trimesters and part of the first trimester, although there are uncertainties with this estimate.

It is important to estimate the fetal radiation dose in pregnant patients who undergo radiography, CT, or fluoroscopy, and the medical physicist is actively involved in this process [32]. At Harborview Medical Center, a thermoluminescent dosimeter is placed on the abdomen of all pregnant patients imaged with radiography, CT, and fluoroscopy. The skin

### TABLE 2: Fetal Absorbed Dose from Selected Radiographic Examinations

<table>
<thead>
<tr>
<th>Examination</th>
<th>Fetal Absorbed Dose (mGy)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cervical spine (anteroposterior, lateral)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Extremities</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Chest (posteroanterior, lateral)</td>
<td>0.002</td>
</tr>
<tr>
<td>Thoracic spine (anteroposterior, lateral)</td>
<td>0.003</td>
</tr>
<tr>
<td>Abdomen (anteroposterior)</td>
<td>1–3</td>
</tr>
<tr>
<td>Lumbar spine (anteroposterior, lateral)</td>
<td>1</td>
</tr>
<tr>
<td>Background fetal dose for 9 months of pregnancy</td>
<td>0.5–1</td>
</tr>
</tbody>
</table>

Note.—Doses to conceptus and background dose to the conceptus obtained from [33]. A radiation shield is applied over the gravid abdomen when not in the imaging field.

### TABLE 3: Fetal Absorbed Dose from Selected CT Examinations

<table>
<thead>
<tr>
<th>Examination</th>
<th>Fetal Absorbed Dose (mGy)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CT head</td>
<td>0</td>
</tr>
<tr>
<td>CT chest</td>
<td>0.2</td>
</tr>
<tr>
<td>Pulmonary CT angiography</td>
<td>0.2</td>
</tr>
<tr>
<td>CT abdomen</td>
<td>4</td>
</tr>
<tr>
<td>CT abdomen and pelvis</td>
<td>25</td>
</tr>
<tr>
<td>CT kidneys, ureters, and bladder</td>
<td>10</td>
</tr>
<tr>
<td>Background radiation for 9 months of pregnancy</td>
<td>0.5–1</td>
</tr>
</tbody>
</table>

Note.—A radiation shield is typically applied over the gravid abdomen when not in the imaging field.

<table>
<thead>
<tr>
<th>Reference</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>a</td>
<td>Reference</td>
</tr>
<tr>
<td>b</td>
<td>CT doses to conceptus and background dose to the conceptus obtained from [33].</td>
</tr>
<tr>
<td></td>
<td>CT doses to conceptus obtained from [33].</td>
</tr>
</tbody>
</table>
CT in Pregnancy

Normal Appearance of the Gravid Uterus

It is important to recognize the normal appearance of the gravid uterus when reading CT scans in pregnant women. In the first trimester, the gestational sac is seen as a low-attenuation endometrial cystic structure. There may be pronounced endometrial enhancement. The placental site is identified late in the first trimester [12, 43] (Fig. 2A). In the second trimester, early ossification of fetal parts is seen. The placenta heterogeneously enhances and is clearly delineated from underlying myometrium. Deep in relation to the placenta are enhancing engorged veins representing the retroplacental venous plexus [12, 43] (Fig. 2B). Beginning late in the second trimester, the placental cotedulons become well formed and are characterized by central areas of low attenuation with intervening rings of higher attenuation [12, 43]. The fetal skeleton is ossified with clearly delineated organs. Very little IV contrast material crosses the placenta into the fetal circulation, and there is no detectable enhancement of fetal tissue [12] (Fig. 2C). Throughout gestation, the normal amniotic fluid is low density [12].

Physiologic Changes of Pregnancy

Over the course of pregnancy, the cardiac output increases from 4.5 to 6.0 L/min, with uterine blood flow increasing from 1% to 10% of the cardiac output [44]. Physiologic changes of pregnancy may be observed on CT in the second and third trimesters. The pelvic and ovarian veins enlarge, the latter approaching the size of the IVC [3] (Figs. 2B and 2C). The spleen enlarges as much as 50% during pregnancy [45]. Maternal hydronephrosis (greater on the right) is common in pregnancy with the kidneys enlarging by up to 1.5 cm [46] (Fig. 2D). Laxity of the pelvic ligaments results in mild widening of the symphysis pubis and sacroiliac joints. One may observe a rim-enhancing corpus luteum cyst in the ovary in the first trimester [12].

Traumatic Injuries in Pregnancy

Maternal Injury

The pregnant patient is predisposed to the same spectrum of injuries encountered in nonpregnant trauma patients. However, retroperitoneal hemorrhage is more common in pregnant trauma patients because of increased pelvic blood flow [3] (Fig. 3). The gravid uterus displaces the liver and spleen against the ribs and elevates the bladder out of the pelvis, making these more prone to injury [3, 20]. Moreover, as the kidneys and spleen enlarge, they are more susceptible to injury [3] (Fig. 4). Certain injuries in pregnancy are associated with an increased risk of fetal loss. Pelvic and acetabular fractures occurring in pregnancy are associated with a high maternal (9%) and higher fetal (35%) mortality, increasing to 75% for severe fracture patterns [47] (Fig. 5). In penetrating abdominal trauma, uterine and fetal injury increase as the gravid uterus enlarges, while offering greater maternal protection [18]. When the mother survives, the most common causes of fetal death are placental abruption and maternal hemorrhage. A pregnant woman can lose 30% of her blood volume before her vital signs change [20]. Because there is no uterine autoregulation, maternal blood pressure does not accurately reflect uterine blood flow. Maternal hemorrhage causes pronounced uterine artery vasoconstriction that protects maternal hemodynamics while leading to fetal hypoxia, acidosis, and even death [3, 4, 20]. Severe maternal head injury is associated with an increased risk of fetal loss thought to be due to alteration in the hypothalamic-pituitary-adrenal axis [4, 9] (Fig. 4). Maternal death almost always results in fetal death. Head injury and hemorrhagic shock account for the majority of maternal deaths. The maternal death rate from serious injuries is no different from the death rate in nonpregnant trauma victims [3].

<table>
<thead>
<tr>
<th>Weeks After Conception</th>
<th>Stage of Development</th>
<th>Biologic Effects to Conceptus</th>
</tr>
</thead>
<tbody>
<tr>
<td>0–2 weeks</td>
<td>Preimplantation</td>
<td>Prenatal death (all or none)</td>
</tr>
<tr>
<td>2–8 weeks</td>
<td>Major organogenesis</td>
<td>Risk at &gt; 50–100 mGy</td>
</tr>
<tr>
<td>2–15 weeks</td>
<td>Organogenesis and rapid neuronal development and migration</td>
<td>Organ malformations</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Risk threshold &gt; 100 mGy (but not observed in humans at diagnostic levels)</td>
</tr>
<tr>
<td>2 weeks to term</td>
<td>Postimplantation</td>
<td>Small head size</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Risk threshold &gt; 100 mGy</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Severe mental retardation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Risk threshold &gt; 100 mGy</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Childhood cancer (&lt; 15 years old)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Risk childhood cancer death 0.06% per 10 mGy (or 1/1700)</td>
</tr>
</tbody>
</table>

|a|Data from [28].
|b|Data from [31].
|c|Data from [28].
Injury to the Gravid Uterus

Complications of trauma to the gravid uterus include spontaneous abortion, preterm labor, premature rupture of membranes, placental abruption, placental laceration and infarction, and uterine laceration and rupture. Most injuries to the gravid uterus occur in the third trimester.

The most common injury to the gravid uterus after blunt trauma is placental abruption. Abruption is the result of shearing between the relatively elastic uterus and rigid placenta. The incidence of placental abruption is 1–5% with minor trauma and 30–50% with major trauma [2, 3, 5]. Risk factors independent of trauma include advanced maternal age, tobacco use, cocaine use, maternal hypertension, and preeclampsia [48]. Clinically, placental abruption presents with uterine pain and irritability with or without vaginal bleeding. Marginal placental abruption occurs when there is uteroplacental separation at the placental margin. Retroplacental abruption involves the central placenta and carries a worse prognosis. Placental abruption can lead to preterm labor, fetal distress, low birth weight, oligohydramnios, fetal death, and maternal coagulopathy secondary to release of thromboplastin substances from the placenta [3]. Small placental abruptions may be well tolerated. The larger the abruption, the worse the prognosis, with greater than 50% abruption leading to 75% fetal mortality [48–50].

In minor trauma when there is no concern for maternal injury but there is concern about the pregnancy, radiologists often perform ultrasound to diagnose placental abruption. Unfortunately, ultrasound is insensitive for abruption and is false-negative in 50–80% of cases [20, 48, 51]. Therefore, a negative ultrasound cannot exclude placental abruption. When positive, ultrasound shows retroplacental hemorrhage that is hyperechoic acutely, becoming hypoechoic over time. It may be isoechoic to the placenta at the time of scanning, in which case one only observes apparent focal thickening of the placenta [52] (Fig. 6). The normal placenta measures 1 mm thick for each week of gestation. At 30 weeks, the normal placenta is 30 mm thick [48, 53]. Normal retroplacental venous plexus can be differentiated from retroplacental hemorrhage by applying color Doppler ultrasound. With placental abruption, one may also see echogenic amniotic fluid due to bleeding into the amniotic cavity [53].

The diagnosis of placental abruption may be made on CT when the pregnant trauma patient is scanned to exclude maternal injury. A lacerated or partially devascularized placenta may be seen as focal diminished enhancement extending from the placental base to the placental surface [12, 43] (Figs. 7 and 8). Over time, this may lead to placental infarction. One may see apparent focal placental thickening from retroplacental clot that may be difficult to distinguish from normal placenta or a myometrial contraction [43]. With placental abruption, one may occasionally see hyperdense amniotic fluid from bleeding into the amniotic cavity [12]. The accuracy of CT in the diagnosis of placental abruption in the pregnant trauma patient is controversial. Most studies to date lack scientific rigor due to small patient numbers and the lack of a reference standard [43, 54]. Certainly, CT is not recommended for diagnosing placental abruption in pregnancy because of the risks of ionizing radiation in pregnancy. However, when CT is performed to diagnose maternal injuries, it is important for the radiologist to recognize placental abruption when evaluating the gravid uterus.

CT may be false-negative in predicting placental abruption (Fig. 9). Conversely, chronic placental infarcts in late third trimester pregnancies may cause a false-positive diagnosis for placental abruption [43] (Fig. 10). The CT appearance of late third trimester placen- tas may also be confusing due to prominent chorionic villous plate indentations that may resemble ischemic changes and venous lakes that may resemble active bleeding into the placenta (Figs. 5 and 11). The imaging findings are always correlated with the external fetal monitoring, which remains the most sensitive test to diagnose placental abruption. Findings of placental abruption and fetal distress on external fetal monitoring prompt emergency cesarean section [3] (Fig. 1). Delayed scanning would significantly contribute to fetal dose and is not performed to evaluate the placenta.

Uterine laceration and rupture are uncommon, seen in less than 1% of pregnant major trauma patients [21]. Uterine rupture is one of the most life-threatening emergencies in obstetrics [14], associated with near 100% fetal mortality. Maternal mortality occurs in fewer than 10% of cases and usually results from associated injuries [3, 55]. Prior cesarean section, previous uterine surgery, and congenital uterine anomalies [14] increase the risk for uterine rupture in blunt trauma. Penetrating trauma is an independent risk factor [21, 56]. Patients present with pain, shock, and absent fetal heart tones. The diagnosis of a uterine laceration is difficult with ultrasound [56, 57]. On CT, a uterine laceration presents as diminished enhancement of the myometrium, which may appear thinned with deep or full-thickness lacerations [12, 56]. The most extreme cases present with an empty uterus and free-floating fetus surrounded by amniotic fluid, blood, and sometimes placenta [12, 56] (Fig. 12).

Injury to the Fetus

Direct fetal injury is uncommon in the pregnant trauma patient because the fetus is afforded protection by the maternal body wall, uterus, and amniotic fluid [3, 21]. By the late third trimester, the volume of amniotic fluid relative to the volume of the fetus is decreased, providing less cushion effect. The most common injuries to the fetus are skull fracture and head injury, seen in the late third trimester with cephalic presentation, often in the setting of a maternal pelvic fracture [58] (Fig. 8). Fetal head injury is almost universally lethal to the fetus [59].

Penetrating Trauma

Penetrating trauma in pregnancy is less common than blunt trauma, accounting for 9% of abdominal trauma in pregnancy in one series [18]. Most result from gunshot wounds [18]. The gravid uterus offers protection to the mother; however, direct uterine and fetal injuries are increased [14, 17, 18, 56]. The fetal death rate is 71–73% for uterine gunshot wounds and 27–42% for stab wounds [17, 21, 60].

Prevention

Trauma is the leading cause of nonobstetric maternal mortality, and much attention has been drawn to prevention. Most serious injuries occur as a result of motor vehicle crashes. Fetal mortality is 1–2% from minor crashes, rising to 30–50% in major crashes [61]. Properly placed shoulder-lap belts have protective effects on the mother and her fetus in all trimesters of pregnancy, and their use is recommended by the National Highway Traffic Safety Administration (NHTSA) and the American College of Obstetrics and Gynecology. However, many pregnant women do not use seat belts or do not use them correctly [4, 62]. The lap portion should be placed as low as possible on the hips, never above the abdomen because this may cause injury to the gravid uterus [21, 63]. The use of airbags in pregnancy is controversial. Airbags deploy at high velocity and at high force, and the force is greater the closer one is to the airbag deployment device [64]. In the third trimester of pregnancy, the gravid uterus may be
positioned very close to the airbag deployment device and is susceptible to strong forces if the airbag deploys. Airbag deployment has been implicated in direct fetal injury and placental abruption in late third trimester pregnancies in several case reports [65–67]. Depowered and multistage airbags are being installed in newer vehicles for safety reasons [64]. The NHTSA is currently evaluating its position on the use of airbags in pregnancy [63]. As a rule, drivers and passengers should sit at least 10 inches (25 cm) from the airbag deployment device. If this is not possible, the airbag should be disconnected [62].

Domestic violence is such an important cause of trauma in pregnancy that pregnancy itself is an independent risk factor for trauma in young women. The trauma from domestic violence is often directed at the gravid abdomen [14] and may threaten the mother and her pregnancy [11, 68]. Up to 10% of abused women are pregnant, with a miscarriage rate of 5% [68]. Emergency personnel should routinely inquire about domestic violence when pregnant women present for medical care.

Substance abuse is a common problem in trauma victims, including pregnant women. The incidence of substance abuse in pregnant trauma patients in the form of drugs or alcohol is 13–20% [4]. Prenatal care visits should include prevention programs aimed at reducing substance abuse, especially in young women.

Conclusion

Trauma is the leading cause of nonobstetric maternal mortality and a significant cause of fetal loss. Managing the pregnant trauma patient requires a multidisciplinary approach. In high-energy trauma when there is concern for maternal injuries, CT is the mainstay of imaging. The risks of radiation to the pregnancy are small compared with the risk of missed or delayed diagnosis of trauma. With rare exception, there is no fetal survival without maternal survival and imaging should be performed without delay. Radiologists must be familiar with the normal and abnormal appearance of the gravid uterus in pregnant trauma patients undergoing CT. In low-energy trauma when there is no concern about maternal injuries but there is concern about the fetus, ultrasound is performed to evaluate the pregnancy. Radiologists must be aware that ultrasound is insensitive in diagnosing placental abruption and a negative ultrasound examination does not exclude this diagnosis. External fetal monitoring is used to dictate patient care. Trauma prevention is important in pregnancy. Pregnant patients are advised to wear seat belts correctly when in a motor vehicle. The use of airbags is controversial.

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Abdominal Trauma and Pregnancy


55. Harrison SD, Nghiem HV, Shy K. Uterine rupture with fetal death following blunt trauma. AJR 1995; 165:1452


Fig. 1.—Readout from external fetal cardiotocography monitoring in woman with placental abruption requiring emergency cesarean section. Uterine contractions are occurring every minute with increasing baseline tone as tracing evolves (lower strip). Fetal heart rate shows variable-appearing deceleration evolving into prolonged fetal deceleration (upper strip). Toward end of tracing, fetal heart signal is lost and when regained, fetal heart rate is in 70–80 beats/min (bradycardic) range, warranting emergency cesarean section. (Reprinted with permission from [69])

Fig. 2.—Normal CT of gravid uterus.
A, 35-year-old woman who is 8 weeks pregnant. Normal first trimester CT image of gravid uterus shows intrauterine gestational sac as low-attenuation cystic structure. There is pronounced endometrial enhancement (arrow). Placentation site is not visualized.
B, 33-year-old woman who is 15 weeks pregnant. Normal CT image of gravid uterus shows early ossification of fetal parts. Placenta (P) is forming on right side of uterus with heterogeneous enhancement. There are enhancing engorged veins deep in relation to placenta representing retroplacental venous plexus (arrowheads). There is marked enlargement of pelvic veins bilaterally (arrows).
C, 26-year-old woman who is 26 weeks pregnant. Normal late second trimester CT image of gravid uterus shows anterior placenta with well-defined cotyledons characterized by central areas of low attenuation with intervening rings of higher attenuation (asterisks). Fetal parts are ossified and amniotic fluid is low density. Very little iodinated contrast material crosses placenta, so there is no enhancement of fetal liver (L). Right ovarian vein is enlarged to one half size of inferior vena cava (arrow).
D, 24-year-old woman who is 35 weeks pregnant. Normal third trimester CT image of gravid uterus and kidneys shows bilateral hydronephrosis, greater on right (arrows). Placenta is posterior with heterogeneously enhancing cotyledons (asterisks).
Abdominal Trauma and Pregnancy

Fig. 3—25-year-old intoxicated woman who is 21 weeks pregnant and was restrained passenger in head-on high-speed motor vehicle crash.
A, Contrast-enhanced CT image of abdomen and pelvis shows right retroperitoneal hemorrhage (asterisk) centered on enlarged right ovarian vein (arrowhead).
B, CT image through gravid uterus shows normal anterior placenta. Arrowheads show nonenhancing chorionic villous plate indentations that should not be confused with abnormality. There are enhancing engorged veins in right adnexa (asterisk). Patient also sustained multiple pelvic and acetabular fractures (not shown). Mother and fetus did well.

Fig. 4—18-year-old woman who is 14 weeks pregnant and was restrained passenger in T-bone high-speed motor vehicle crash.
A, CT image of head shows shear hemorrhage in splenium of corpus callosum (arrow) and small amount of intraventricular blood (not shown).
B, Contrast-enhanced CT image through abdomen shows grade 2 splenic laceration (arrowhead) and small hemoperitoneum (arrow).
C, CT image through gravid uterus is normal with anterior placenta (arrow) and early ossification of fetal parts (arrowhead). There is small hematoma in left pelvic sidewall (asterisk) due to pelvic fracture. Patient had lateral compression injury of bony pelvis with zone 1 fracture of left sacral ala and left obturator ring fracture (not shown). CT cystography performed for hematuria was negative for bladder injury (not shown).
D, Limited obstetric ultrasound image obtained next day shows fetal death with intrauterine gestation with no fetal cardiac activity. Placenta was normal on ultrasound. Patient was treated with dilatation and curettage and had internal fixation of pelvic fracture.
Fig. 5—38-year-old woman who is 38 weeks pregnant and is hemodynamically stable. She was restrained driver in high-speed motor vehicle crash. 

A and B, CT images through pelvis show diastasis of left sacroiliac joint (arrowhead, A) and bilateral obturator ring fractures (arrows, B) from anteroposterior compression injury.

C, Contrast-enhanced CT image of abdomen and pelvis shows areas of nonenhancement in posterior placenta (asterisk) concerning for ischemia and areas of contrast blush (arrow) concerning for active bleeding. Venous lakes and chorionic villous plate indentations provide alternate explanation because external fetal monitoring at this time was normal (see also Fig. 11). Delayed scans are not performed to evaluate placenta because it would not change management and would significantly add to fetal dose.

D, CT image through pelvis shows large hematoma deep in relation to left groin with active contrast extravasation (arrow).

E, Emergency angiogram with selective injection of left external iliac artery shows active extravasation from left inferior epigastric artery (arrow) that was treated with embolization coils. Later, in ICU, there were increasing uterine contractions and worrisome fetal heart tones on external fetal monitoring concerning for placental abruption prompting emergency cesarean section. Mother and infant did well. Pelvic fracture was treated conservatively.

Fig. 6—19-year-old woman who is 24 weeks pregnant and sustained multiple blows to her abdomen in mosh pit 1 week before admission. Moshing is form of slam dancing. She had uterine contractions over past week and developed severe abdominal pain and vaginal bleeding on day of admission.

A, Color Doppler ultrasound image of placenta (P) shows apparent thickening of placenta due to large retroplacental hematoma (H) that is heterogeneously hypoechogenic to placenta without internal color flow.

B, Follow-up ultrasound image of placenta obtained 3 weeks later after bed rest in hospital reveals contraction of clot (H) that has become hypoechogenic to placenta (P). There was no rupture of membranes. Vaginal bleeding and uterine contractions stopped. Patient was discharged with close interval follow-up. (Reprinted with permission from [69])
Abdominal Trauma and Pregnancy

**Fig. 7**—23-year-old woman who is 20 weeks pregnant and was pedestrian hit by car on right side of her body. **A** and **B**, Contrast-enhanced CT images of abdomen and pelvis show grade 4 hepatic laceration (arrow) and small hemoperitoneum. There is normal bilateral hydrenephrosis of pregnancy. **C**, CT image through gravid uterus shows posterior placenta with marginal placental abruption on left with intermediate-density clot elevating placenta from uterine wall (asterisk). Engorged right ovarian vein (arrow) and dilated ureters (arrowheads) are normal in pregnancy. She also sustained comminuted right femur fracture (not shown). Ultrasound revealed normal fetal heart tones and movement. Femur fracture was treated with open reduction and internal fixation, and patient had subsequent uneventful pregnancy.

**Fig. 8**—20-year-old woman who is 39 weeks pregnant and was restrained driver who swerved head on into traffic and was T-boned by bus on driver’s side at 60 miles/h (96.6 km/h) with airbag deployment. She was intubated at scene for loss of consciousness. **A**, Contrast-enhanced CT image of abdomen and pelvis shows placenta on right with near-complete devascularization indicative of severe abruption (asterisk). There are only small areas of enhancing placenta (arrowhead). Patient was in right posterior oblique position rather than left, and there is compression of inferior vena cava by gravid uterus (arrow). **B**, CT image obtained lower through gravid uterus shows cephalic presentation of fetus. There is displaced fracture of right fetal parietal bone (arrow) with intracranial blood (asterisks). **C**, Bone windows image shows zone 2 left sacral fracture (arrow) and fracture of left obturator ring (not shown). While in CT, patient showed evidence of preterm labor and worrisome fetal heart tones. Emergency cesarean section was performed immediately after CT for placental abruption. Surgery confirmed retroplacental clot and bloody amniotic fluid. Infant had Apgar scores of 1–1-1 and died after 34 minutes of resuscitation. Autopsy report revealed that cause of death was fetal head injury with skull fracture, brain laceration, and intracranial hemorrhage. Mother did well. (Reprinted with permission from [58])
Fig. 9—33-year-old woman who is 33 weeks pregnant and sustained 20-foot fall from balcony after using alcohol and cocaine. 
A, Contrast-enhanced CT image of abdomen and pelvis shows anterior placenta (asterisk) that appears normal. 
B and C, CT images of pelvis show diastasis of sacroiliac joints (arrows, B) and symphysis pubis (arrow, C) from anteroposterior compression injury. There is also hematoma in space of Retzius without active contrast extravasation (not shown). Patient also had open comminuted intraarticular distal left femur fracture (not shown). External fetal monitoring showed moderate fetal heart rate variability and minimal contractions early on. Later on day of admission, there were fetal decelerations and increased uterine contractions in keeping with placental abruption. Patient had emergency cesarean section and delivered live infant. She was treated for her injuries.

Fig. 10—22-year-old woman who is 31 weeks pregnant and was involved in motor vehicle crash. Contrast-enhanced CT image of abdomen and pelvis shows several areas of nonenhancing placenta (asterisk). Obstetric ultrasound and ultrasound of placenta were normal. Patient sustained no other injuries. External fetal monitoring over 4 hours was normal. Patient was assumed to have had chronic placental infarcts unrelated to acute trauma and was discharged.

Fig. 11—39-year-old woman who is 39 weeks pregnant and was restrained front seat passenger in rear-end motor vehicle crash. She has history of juvenile rheumatoid arthritis and was scheduled for elective cesarean section in 2 days. 
A and B, Contrast-enhanced CT images of abdomen and pelvis show multiple areas of nonenhancement of placenta, most pronounced on amnionic surface (asterisk). There are also areas of contrast medium pooling (arrow, A) that were concerning for active bleeding into placenta at time. Incidental note is made of enhancing fibroid in posterior left uterine body (F) in A, necrotic fibroid deep in relation to placenta in right uterine body (F) in B, and engorged veins in right pelvic sidewall (arrow, B). External fetal monitoring showed contractions every 5–8 minutes but normal fetal heart tones. There was no vaginal bleeding. Ultrasound of pregnancy and placenta showed normal findings. Patient underwent regularly scheduled cesarean section 2 days later with no complications. Obstetrician did not report anything unusual about placenta. Patient sustained no other injuries. It is thought that unusual appearance of placenta was due to prominent chorionic villous plate indentations and venous lakes rather than sequela of trauma. Delayed imaging is not performed to evaluate placenta because it would not change management and would significantly add to fetal dose.
Fig. 12—Woman who is 36 weeks pregnant and was restrained passenger in motor vehicle crash. Fetal heart tones and motion were absent at screening ultrasound. A and B, Contrast-enhanced CT images of abdomen and pelvis show uterine rupture with free floating fetus (F, A) and empty uterus (U, B). There is free intraperitoneal fluid that may represent blood and amniotic fluid. Complete posterior fundal rupture was found at surgery and extruded fetus was dead. Patient recovered from her other injuries. (Reprinted with permission from [12])