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Trauma complicates 6% to 7% of all pregnancies.¹ Emergency department (ED) physicians and nurses will find themselves frequently caring for pregnant women who have suffered a variety of traumatic injuries, ranging from minor to life-threatening. These cases will be complicated by a variety of issues, including pregnancy-associated physiologic changes, imaging/radiation risks, limitations in medication use, and fetal monitoring/tocometry.

Emergency health care providers must be comfortable with the unique issues surrounding the evaluation and treatment of pregnant trauma patients and approach each pregnant woman in a systematic fashion.

— The Editor

Epidemiology

Trauma is the leading cause of death among women of child-bearing age. Trauma requiring hospitalization complicates 0.4% of pregnancies. Overall maternal morbidity and mortality after

trauma are not increased by the gravid state; however, pregnancy alters the injury patterns.² Motor vehicle crashes are the leading cause of trauma in pregnancy, followed by physical violence and falls.²⁻⁴ Maternal morbidity from trauma during pregnancy is related to an increased propensity to develop disseminated intravascular coagulation (DIC) due to placental factors, an increased rate of fracture complications, and increased abdominopelvic blood flow, leading to increased blood loss

and development of retroperitoneal bleeding.⁵ In addition, the presence or risk of preterm labor and the need for fetal monitoring are justifications for increased maternal hospitalization. Motor vehicle crashes have been identified as the most common cause of preterm labor requiring admission.³

Trauma is the most common cause of nonobstetric maternal death in pregnancy. (Maternal death is defined as death during pregnancy or within 42 to 90 days after delivery.⁶⁻¹⁰) In some areas of the United States, injuries are the most common cause of

Trauma in Pregnancy

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maternal death.⁶ In recent studies comparing rates and causes of maternal death, the number of deaths from obstetric causes is decreasing.^{7,8} In contrast, deaths from injuries (including unintentional and suicidal) account for more than half of nonobstetric deaths, and the number resulting from homicide is increasing.⁹

Fetal Morbidity and Mortality. Even mildly injured (Injury Severity Score [ISS] 1-8) pregnant women are at risk for placental abruption, and their fetuses are at risk for hypoxia, respiratory distress syndrome, and death.¹¹ Less commonly reported fetal injuries sustained in motor vehicle collisions include brain trauma and spinal fracture.^{12,13} When the fetal head is engaged in the pelvis or maternal pelvic fractures are present, the likelihood of fetal skull and brain injuries is increased.¹⁴ The fetus is at greatest risk of suffering injury or death during the time immediately following trauma. Rare case reports document severe intrauterine fetal neurologic injury undetected during trauma evaluation.¹⁵

Maternal death is the most common cause of trauma-associated fetal death. Following maternal trauma, fetal death rates have been reported between 4% and 61%, depending upon length of follow-up and injury severity.¹⁶ Motor vehicle crashes are the predominant traumatic mechanism causing fetal death, distantly followed by penetrating trauma (caused by firearms) and falls. The prevalence of fetal injury and loss is difficult to determine, because of underreporting of these events in vital statistics reports and injury surveillance systems.¹⁷

Multiple studies have attempted to identify maternal factors predictive of poor fetal outcome. Fetal death has been associated

with an increased maternal ISS and abnormal maternal physiology on presentation, including shock. Severe truncal injuries also have been associated with increased fetal loss.² In one large multi-institutional study, fetal deaths occurred in 50% of patients with an ISS more than 25.¹⁸ Fetal loss also was associated with maternal shock (e.g., systolic blood pressure < 90) or a fetal heart rate less than 110 bpm. The most frequent fetal complication was premature labor; 5.9% of patients in this study delivered prematurely, 95% delivering viable neonates. Placental abruption occurred in 3.5% of patients and was associated with a 54% mortality. Other complications included premature rupture of membranes and uterine perforation or rupture. Overall, 72.3% of the 372 patients studied did not have fetal complications.¹⁸ In another study, patients with placental abruption had a much lower ISS (< 2). In this population, placental abruption occurred in 6.8% of patients. An ISS of 4 was associated with fetal death.¹⁹ Together, these studies illustrate that ISS alone should not be used to determine risk of placental abruption or fetal death; women with relatively minor injuries can sustain adverse pregnancy outcomes.

Physiology

The emergency care provider should be familiar with the physiologic changes of pregnancy (*Table 1*). These changes cause a pregnant woman's response to injury to be different from what is expected in a nongravid female. Trauma resuscitation of a pregnant female without consideration of these physiologic changes may contribute to high fetal death rates.²⁰

Cardiovascular. Plasma volume is increased significantly during pregnancy. By the end of the first trimester, plasma volume has increased 40% to 50%.²¹ Red blood cell mass also increases, but to a lesser degree, resulting in a dilutional anemia. This increased blood volume provides maternal protection against blood loss during delivery. However, an injured pregnant woman can lose up to 2000 mL of blood without developing any signs of hemodynamic instability.²¹ Trauma care providers must be vigilant in their search for possible bleeding, even when the patient exhibits normal vital signs.

Blood pressure and heart rate also are affected by pregnancy. Baseline blood pressure decreases, secondary to progesterone-related vascular relaxation. During the second trimester, baseline systolic and diastolic blood pressures are lowered by 5 to 15 mmHg, making interpretation of blood pressure difficult in the presence of hemodynamic compromise. Baseline heart rate during pregnancy increases 15 bpm, complicating evaluation for occult hemorrhage. There are multiple case reports of pregnant women with presumably normal vital signs after trauma, who suffered significant internal injuries, including uterine rupture and placental abruption. Because of these factors, the care provider must have a high level of suspicion for injury.

Elevated blood pressure has different implications for pregnant and nonpregnant trauma patients, as it may be an indicator of pre-eclampsia and eclampsia. (The clinical triad that heralds eclampsia comprises seizures, elevated blood pressure, and proteinuria.) Pre-eclampsia also has been associated with transient blindness.²² If a woman in the third trimester presents to the ED

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Table 1. Normal Physiologic Changes of Pregnancy Relevant to Trauma Care

PARAMETER	CHANGE	IMPLICATION
Maternal blood volume	Increased	Attenuated initial response to hemorrhage
Cardiac output	Increased	Increased metabolic demands
Uterine enlargement	Enlarged	Propensity for supine hypotension from aortocaval compression
Functional residual volume	Decreased	Hypoxemia from atelectasis more likely
Gastrointestinal motility	Decreased	Greater risk of aspiration
Minute ventilation	Increased	Compensated respiratory alkalosis, diminished buffering capacity

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with altered mental status after being involved in a motor vehicle collision or after being found after a presumed or witnessed seizure, eclampsia should be considered as a cause of the incident. Appropriate laboratory studies include complete blood count, blood urea nitrogen, creatinine, liver function tests, and a coagulation profile. Eclampsia is treated with a magnesium sulfate drip. Definitive treatment is delivery of the fetus, as placental factors contribute to the disease. An obstetrician should be involved in the decision-making process when managing a trauma patient with potential eclampsia.

Cardiac output increases 40% during pregnancy. During the third trimester (> 24 weeks), supine positioning of the patient will cause significant aortocaval compression, resulting in a 25% reduction in cardiac output and dropping systolic blood pressure by as much as 30 mmHg.²³ This condition can be alleviated by placing the patient in a left lateral tilt position, which can be accomplished by placing a towel, bag of saline, or wedge under the backboard or under the patient if she has no evidence of spinal injury.²¹ Uterine blood flow at term approaches 600 mL per minute. Rapid exsanguination can occur from uterine bleeding.²⁴

Pulmonary. Respiratory changes in pregnancy also affect the patient's response to trauma. Minute ventilation increases due to increased tidal volume, resulting in a compensated respiratory alkalosis with increased excretion of bicarbonate. Pregnant patients tolerate acidosis poorly because they have little buffering reserve capacity. Functional residual volume also is decreased, increasing the patient's propensity to develop hypoxia. Atelectasis contributes to hypoxia in the supine pregnant patient as a result of increased abdominal girth. Because of these factors,

after becoming apneic, a pregnant woman will become hypoxic more rapidly than a nonpregnant woman.

Pregnant patients are at increased risk of pulmonary embolism, because of changes in coagulation factors and venous stasis. In patients who report syncope, shortness of breath, or chest pain prior to the traumatic event, pulmonary embolism should be considered as a possible factor leading to the injury.

Other. Gastrointestinal motility is decreased by circulating progesterone.²⁴ Thus, many pregnant women have increased gastric reflux and are at an increased risk for aspiration.

Glomerular filtration rate and creatinine clearance are increased in pregnancy. These increases lower baseline serum creatinine levels (< 0.9 mg/dL) and blood urea nitrogen levels (<15 mg/dL), and modest increases may represent significantly impaired renal function.²⁰

Pregnancy induces a hypercoagulable state by increased hepatic production of clotting factors, increasing maternal risk of thromboembolism.²⁴ An increase in the baseline level of fibrinogen in a pregnant patient is important when evaluating for the presence of DIC.²¹

Initial Management

Prehospital. Emergency medical services personnel are usually the first care providers who have contact with pregnant trauma patients. The most important initial factor in fetal outcome is the status of the mother; therefore, maternal resuscitation should come before attempts to assess the fetus. If the patient is of child-bearing age but does not appear pregnant, she should be asked if she could be pregnant. If the estimated fetal age is more than 20 weeks, a hospital with a neonatal intensive care unit is preferred, but may not be available.²³ Fetal gestational age more than 20 weeks, may be estimated by a uterine fundal height between the umbilicus and xiphoid.²⁵ After the patient is placed on the backboard, the board should be placed in the left lateral decubitus position using blocks, towels, or a liter bag of saline. When supine, pregnant patients develop hypoxia easily and should receive supplemental oxygen. Two large-bore intravenous lines should be placed and aggressive crystalloid fluid resuscitation begun. En route to the trauma facility, all treatment should be guided by maternal status, not by suspected fetal distress.

Primary Survey. In the trauma center's receiving unit, initial management of the pregnant patient should focus on the maternal primary survey (evaluation of the airway, breathing, circulation, disability, and exposure or environment).²⁶ All women capable of childbearing should be tested for pregnancy. Supplemental oxygen should be given to achieve a hemoglobin saturation level greater than 90%.¹ If there is airway occlusion or danger of not protecting the airway adequately, rapid sequence intubation should be performed. Special considerations for intubation include physiologic and pharmacological issues. Induction and narcotic medications cross the placenta; paralytic agents are larger molecules and do not cross the placenta.²⁷ Although no consensus has been published regarding the selection of induction agents during pregnancy, etomidate and succinylcholine commonly are used. Success also has been reported without compli-

cations using ketamine and succinylcholine.²⁸ The individual performing the intubation must be prepared for rapid desaturation resulting from decreased functional reserve capacity, despite adequate preoxygenation. During the intubation attempt, the airway mucosa may be edematous and friable. Every attempt should be made to decrease aspiration risk by applying cricoid pressure and immediately placing a gastric tube, because of decreased gastric motility and increased aspiration risk. If a chest tube is required, it should be placed one to two interspaces higher than usual, owing to elevation of the diaphragm by the gravid uterus.²¹ Prior to the circulatory evaluation, the patient should be placed in the left lateral decubitus position to prevent aortocaval compression, while maintaining appropriate spinal immobilization. Crystalloid (lactated Ringer's solution or normal saline) resuscitation should be given as a 3:1 blood loss replacement.¹

Secondary Survey. The secondary survey should include evaluation of fetal heart rate. Fetal heart rate can be heard by Doppler at 10-14 weeks and with a conventional stethoscope at 20 weeks' gestation. A heart rate slower than 120 bpm or faster than 160 bpm should raise suspicion of fetal distress.²⁹ If the fetus is viable (> 23 weeks), continuous monitoring should begin at this time.²³

In addition to the routine portions of the secondary trauma survey, several aspects of the physical examination apply specifically to pregnancy. First, in an unresponsive patient, or one from whom a history cannot be obtained, gestational age must be determined. The umbilicus marks the fundal height that correlates with 20 weeks' gestation. Gestational age beyond 20 weeks' can be estimated by measuring the distance in centimeters from the symphysis pubis to the uterine fundus. Next, the uterus itself should be palpated; it should be palpable but soft. Fetal parts may be palpable as small protusions but should not have discreet form. A firm uterus (with resistance like that of a basketball) is indicative of contraction or tetany. If a discreet uterus cannot be palpated in a woman known to be pregnant, uterine rupture should be considered, especially if individual fetal parts are palpable through the abdominal wall.

The perineal area should be assessed for leakage of fluid (clear or green stained with meconium), bleeding, prolapsed umbilical cord, or fetal parts. If there is leakage but it is not known whether the fluid is urine or amniotic fluid, amniotic fluid placed on a slide, allowed to dry, and then viewed by microscope will exhibit a classic ferning pattern. In addition, amniotic fluid placed on nitrazine paper will turn the paper blue.

Depending upon availability, optimally an obstetrician should perform the internal vaginal examination. In patients with vaginal bleeding, a speculum or bimanual examination should not be performed, because of the possibility of placenta previa (placenta covering the cervical os) and the risk of severe hemorrhage. The Apt test, described later in this article, should be considered to determine the source of any vaginal bleeding. In cases of fetal hemorrhage, exsanguination occurs rapidly, and the time from onset of fetal vaginal bleeding and fetal death is only 1 or 2 minutes. In patients without vaginal bleeding, a careful sterile specu-

lum examination may be performed to assess cervical dilation, to identify or exclude internal trauma, and to look for fluid or amniotic membranes in the vaginal vault or for fetal presenting parts. A sterile bimanual examination should be avoided in preterm patients with leakage of fluid, because the procedure may increase the risk of fetal infectious complications.

Routine examination findings may be altered in pregnant trauma patients. Peritoneal signs may be absent in a pregnant woman despite significant intraperitoneal hemorrhage, owing to stretching of abdominal musculature making the peritoneum less sensitive to irritation.³⁰ In addition, many pregnant patients have low back pain caused by increased forces on the joints, which may present as paraspinal muscle spasm.³¹

History. The history of the trauma should be obtained simultaneously with the secondary survey. In addition to routine questions about the mechanism and cause of injury, loss of consciousness, location of pain, medical history, and allergies, questions specific to pregnancy should be asked. Information regarding gestation and parity should be obtained.

If the patient has delivered in the past, the mode of delivery (cesarean section or vaginal delivery) should be determined. In addition, any complications of pregnancy (current or previous) should be discussed. If the patient knows her Rh status and received RhoGAM (Ortho-Clinical Diagnostics) during the current pregnancy, this should be documented.

Laboratory Studies. Routine laboratory studies generally should be obtained, including complete blood count, basic metabolic panel, hepatic function studies, coagulation studies, toxicology screen, urinalysis, and type and screen.^{25,32} In addition, the fetal DEX test, or Kleihauer-Betke test, should be considered. This quantitative test assesses for fetal blood cells in the maternal circulation. The results can be used to determine the required dose of RhoGAM. In addition, this test frequently is used to monitor patients for ongoing fetal-maternal hemorrhage during prolonged fetal monitoring after trauma.

If a patient is experiencing vaginal bleeding after trauma, it is important to determine whether the bleeding is fetal or maternal in origin. Total fetal blood circulation is very small; thus, if fetal blood is being lost, exsanguination can be rapid with minimal blood loss. Causes of fetal blood loss include umbilical cord avulsion and laceration of a vessel. Maternal vaginal bleeding can be secondary to placenta previa (placental tissue over the cervical os). A placental abruption can present with vaginal bleeding, but usually the blood is trapped behind the placenta. In either case, rapid diagnosis and definitive treatment are necessary to preserve fetal viability.

At the bedside, the Apt test can be performed to distinguish between maternal and fetal sources of vaginal bleeding. To perform this test, blood is placed on a 4 x 4-inch gauze and sodium hydroxide is applied. If the blood changes to dark brown, it is maternal blood, which oxidizes; blood that remains red is fetal.³³ In both cases, prompt obstetric evaluation is necessary.

Diagnostic Testing

Diagnostic testing in trauma patients routinely includes ultrasound evaluation, plain radiographs, and computed tomography (CT) imaging. Care providers must attempt to limit radiation in pregnant patients, and all patients who are able to give consent should be aware of radiation risks prior to undergoing any imaging. In addition, pregnancy may make the films from some of these modalities more difficult to interpret.

Ultrasound. Ultrasound is a valuable tool in the evaluation of nonpregnant and pregnant trauma patients. In emergency ultrasound guidelines published by the American College of Emergency Physicians,³⁴ evaluation of patients in the second and third trimesters focuses on detecting fetal cardiac activity. In the pregnant trauma patient, standard trauma ultrasound (focused assessment with sonography for trauma [FAST]) technique should be performed.³⁴ In addition, longitudinal and transverse views of the uterus should be obtained.³⁵ Uterine views should be used to establish fetal heart rate; to assess the placenta for abnormalities; and to look for gross structural fetal abnormalities, fetal movement, and the presence of amniotic fluid.

Ultrasound evaluation for free intraperitoneal fluid after blunt abdominal trauma is reportedly up to 90% sensitive in nonpregnant and pregnant patients alike, including patients in their third trimester.^{5,37} One study advocates including an assessment for intrauterine pregnancy in the FAST study for all patients of childbearing age.³⁸ In the study population, identification of pregnancy on FAST scan significantly decreased radiation exposure in patients at more than 8 weeks' gestational age. Pregnancies of less than 8 weeks' gestation were not identified by the transabdominal FAST scan; a pregnancy test was required.³⁸ Bochicchio and colleagues suggested consideration of the rapid bedside urine pregnancy test in addition to serum pregnancy testing to have results before the patient is exposed to any radiation.³⁹

Classically, placental abruption is visualized as a retroplacental hematoma (i.e., hypoechogenic area between the placenta and uterine wall) on ultrasound images. However, successful identification by ultrasound occurs in only 50% of trauma patients with placental abruption. Thus, an ultrasound study should not be used to exclude an abruption.^{33,37}

Imaging/Radiation Risks. Radiation in pregnancy has three potentially harmful effects: 1) teratogenesis and cell death, 2) carcinogenesis, and 3) germ cell mutations or genetic effects.⁴⁰

Cell death due to high doses of radiation is presumably an all-or-none phenomenon. Prior to implantation, at 2 to 4 weeks' gestation, it appears that cell death occurs universally. In contrast, a wide range of teratogenic effects of radiation has been documented. Human teratogenic risks of radiation include microcephaly, growth restriction, and mental retardation. During the organogenesis period (4-10 weeks' gestation), the fetus is at greatest risk of developing birth defects. The fetus is at greatest risk of radiation-induced mental retardation at 10 to 17 weeks' gestation, during the period of neurologic development. Radiation levels above 20 rads have been correlated with mental retardation in a dose-related fashion. After 17 weeks' gestation, there

are very rare cases of radiation-induced effects.^{37,40,41}

The risk of developing childhood leukemia is only mildly increased by fetal radiation exposure from 1 in 3000 in the general pediatric population to 1 in 2000 exposed children.⁴⁰ This risk is not related to radiation dose and has been associated with low doses of ionizing radiation. Ultrasound utilizes sound waves and has no documented adverse fetal effects. However, resolution limits usefulness in the trauma setting to evaluating for free fluid and fetal activity. CT scans expose patients to radiation, yet are considered safe below 5 cumulative rads.⁴⁰ In addition, contrast materials are not radioactive and therefore may be given during pregnancy.^{41,42} Magnetic resonance imaging presents no known risks to the fetus but generally is not recommended in the first trimester.⁴⁰ In the future, it may become an important imaging modality in pregnant patients. Gadolinium crosses the placenta and should not be given.^{41,43}

There is no increased risk of fetal anomalies, growth restriction, or spontaneous abortion with a radiation exposure of less than 5 rads (the maximal cumulative dose of ionizing radiation to which a pregnant woman should be exposed).⁴⁴ However, the Committee on Obstetric Practice of the American College of Obstetricians and Gynecologists states that any concern about fetal radiation exposure and risks should not alter the decision to obtain medically indicated maternal radiographic studies and that risks, although real, are not an indication for therapeutic abortion.⁴⁰

Standard initial trauma radiographic studies usually expose patients to near-maximum total pregnancy radiation. Bochicchio and colleagues determined that a standard head, abdominal, and pelvic helical CT scan delivers approximately 4.5 rads.³⁹ In a study involving 3,976 women of childbearing age, the investigators documented that 114 (2.9%) were pregnant. Thirteen of the pregnancies were incidental, either unknown to the woman or known by the woman but unable to be conveyed to the trauma team. Fetal mortality in the incidental group was 77%. Newly diagnosed pregnancies ($N = 9$) were earlier in gestation (6.9 ± 4.2 weeks) than known pregnancies unable to be made known to the trauma team (20.5 ± 5.8 weeks). These women with newly diagnosed pregnancies received more than 5 rads of radiation and had 100% fetal mortality (three by induced abortion, six by spontaneous abortion).³⁹ This study raises the question whether immediate point-of-care testing (e.g., bedside urine human chorionic gonadotropin [hCG]) should be reinstated in an attempt to decrease these fetal losses. However, the care provider must determine whether the medical indication for the test outweighs the significant potential for fetal loss. Of note, controversy exists regarding the 4.5 rads of radiation noted in the aforementioned study, and institutional variance may exist.⁴⁵

Prior to counseling pregnant patients, the emergency physician should discuss radiation exposure with a radiation physicist at his or her institution. It is then important to be honest with patients and families about the risks associated with radiation. Trauma care providers should have figures available to quickly calculate an estimated fetal radiation exposure to explain those risks to the family.⁴⁶ Table 2 is provided as a radiation risk reference.

Table 2. Estimated Fetal Exposure for Various Diagnostic Imaging Methods

EXAMINATION TYPE	EST. FETAL DOSE PER EXAM (RADS)	NO. OF EXAMS REQ FOR A CUMULATIVE 5-RAD DOSE
Plain Films		
Skull	0.004	1250
Dental	0.0001	50000
Cervical spine	0.002	2500
Upper or lower extremity	0.001	5000
Chest (2 views)	0.00007	71429
Abdominal (multiple views)	0.245	20
Thoracic spine	0.009	555
Lumbosacral spine	0.359	13
Pelvis	0.040	125
Hip (single view)	0.213	23
CT scans (slice thickness, 10 mm)		
Head (10 slices)	<0.050	>100
Chest (10 slices)	<0.100	>50
Abdomen (10 slices)	2.600	1
Lumbar spine (multiple views)	3.500	1
Environmental (for comparison)		
Background radiation (cumulative doses over 9 months)	0.100	N/A

Modified from Toppenberg KS, et al. Safety of radiographic imaging during pregnancy. *Am Fam Phys* 1999;59:1813.

Fetal Monitoring/Tocometry

Intrapartum fetal heart rate (FHR) monitoring helps the physician identify acidosis, fetal tachycardia, hypoxia, and umbilical cord compression.⁴⁷ Fetal cardiotocographic monitoring for both FHR and contractions is recommended for at least 4 hours after trauma; after 4 hours of continuous monitoring without complications, outcomes among pregnant women are similar to those of uninjured control patients.^{30,48} Some authors advocate up to 48 hours of continuous monitoring, based upon reports of placental abruption during that length of time after maternal injury. One study identified patients requiring at least 24 hours of monitoring by uterine irritability (at least 6 contractions per hour), abdominal or uterine tenderness, vaginal bleeding, hypovolemia, or non-reassuring fetal heart monitoring.⁴⁹ Obstetricians at specific insti-

tutions frequently have a standard length of monitoring if there are no notable complications.

Prior to the mid-third trimester, it is very difficult to obtain prolonged fetal heart rate tracings, although continuous monitoring is recommended beyond 20 weeks' gestation. To assess fetal well-being, a tocometer belt is applied to the gravid abdomen and the tracing is assessed for contractions or uterine irritability; intermittent fetal heart tones are documented. After blunt abdominal trauma, uterine irritability may signify placental abruption.^{50,51}

In third-trimester pregnancies, fetal cardiac monitoring and tocometry constitute an established method of determining fetal well-being. A normal tracing shows FHR of 120 to 160 bpm with good variability (*Figure 1*). Fetal tracings that should cause concern include those indicating decreased variability in FHR corresponding with early fetal distress (*Figure 2*) or acidosis (*Figure 3*), or late decelerations caused by significant fetal distress such as abruption (*Figure 4*) or fetal bradycardia (FHR < 120 bpm).

Although a normal FHR tracing is associated with good fetal outcome, the reverse is not always true.^{51,52} For the sake of this discussion, any FHR tracing abnormalities should be brought to the attention of the obstetrician immediately. Unfortunately, in one study, fewer than 15% of EDs had cardiotocographic equipment, yet 92% of emergency residents reportedly were taught the indicators of fetal distress.⁵³ This disparity may contribute to the finding that most teaching institutions do not begin continuous fetal monitoring within the first 30 to 60 minutes after presentation, which warrants concern because abruption usually occurs shortly after injury.⁵³

Complications of Trauma During Pregnancy

Fetal injury can be separated into two categories: direct fetal injury and indirect fetal injury caused by placental disruption, uterine injury, maternal shock, or preterm labor.

Prior to 12 weeks' gestation, the uterus is a pelvic organ and relatively protected from abdominal trauma. After the uterus becomes an abdominal organ, it is more susceptible to injury. In addition, increased uterine blood flow makes significant hemorrhage more likely. Some studies show a decreased incidence of injury to other abdominal organs because of the gravid uterus.

Placental Abruption. Placental abruption is the most common cause of fetal demise after blunt abdominal trauma. Placental abruption is the shearing of the placenta from the uterine implantation site. In trauma, this condition likely is secondary to continued forward propulsion of the uterus, with muscular elasticity, without placental adaptation to the change in location and form. Hemorrhage occurs into the new space between the uterus and placenta. As bleeding increases, the expansion can continue to shear the placenta from the uterine wall.

Placental abruption complicates up to 40% to 50% of cases of severe blunt abdominal trauma or major trauma and 1% to 5% of cases of minor trauma.^{5,21,23,25,32} The incidence of abruption is not predicted by the speed or force of trauma. Similarly, injury severity scores do not correlate well with the likelihood of abruption.¹⁹ Abruption frequently occurs soon after the trauma incident, but it can occur up to 48 hours after the initial trauma. One multicenter

Figure 1. Normal Fetal Heart Rate Variability

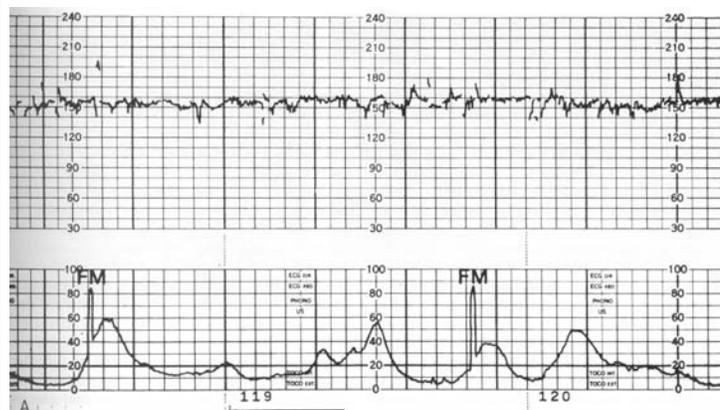


Figure 1. Example of normal fetal heart rate variability with accelerations greater than 15 bpm and longer than 15 seconds.

Reprinted with permission: Druzin ML, et al. Antepartum fetal evaluation. In: Gabbe SG, et al, eds. *Obstetrics: Normal and Problem Pregnancies*, 4th ed. New York:Churchill Livingstone;2002:325.

Figure 2. Fetal Movements

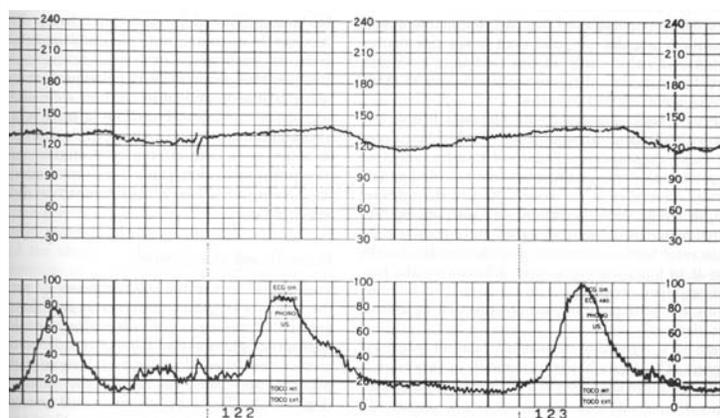


Figure 2. Top: Fetal movement (breaks in continuity of tracing) and no periodic changes. Bottom: Corresponding tocometer tracing.

Reprinted with permission: Benedetti TJ. Obstetric hemorrhage. In: Gabbe SG, et al, eds. *Obstetrics: Normal and Problem Pregnancies*. 4th ed. New York: Churchill Livingstone;2002:511.

study of admitted pregnant trauma patients reported a 3.5% incidence of abruption with resulting 54% mortality.¹⁸ Disseminated intravascular coagulation occurs in up to 30% of patients with traumatic abruption.⁵³

Evaluation for abruption includes a careful physical examination to identify the classic flat, board-like abdomen and vaginal bleeding. Vaginal bleeding caused by blood collecting in the potential space between the uterus and the placenta may or may not be present. Serial evaluations of fundal height may be performed at 15-minute intervals; a rising fundus correlates with concealed abruption.¹⁴ As previously discussed, ultrasound has been utilized to identify and follow placental abruption; however, ultrasound should not be used to exclude the diagnosis.

Assessment of fetal well-being by cardiotocographic monitoring is the most sensitive test for abruption. In a previously mentioned multicenter study, cardiotocographic abnormalities (bradycardia or fetal distress) indicated abruption and led physicians to perform successful cesarean deliveries,¹⁸ the definitive treatment for abruption with fetal distress. If the fetal status is reassuring on the cardiotocographic monitor, the patient can be monitored for a prolonged period and managed conservatively by the obstetrician.

Uterine Rupture. Uterine rupture, tearing of the uterine wall with release of the fetus into the abdominal cavity, occurs in less than 1% of pregnant trauma patients. However, due to the associated very poor maternal and fetal outcomes, uterine rupture is one of the most feared complications of trauma in the pregnant patient. Fetal mortality is 100%, and associated maternal mortality is 10%. The most common site of uterine rupture is the fundus, the superior portion of the uterus. Rupture is more common in patients with a history of previous cesarean delivery. Uterine rupture has been reported with lap belt use without shoulder restraint, airbag deployment, and pelvic fractures.^{21,27} The mecha-

nism of rupture in lap belt and air bag use likely is increased fundal pressure. The association between pelvic fractures and uterine rupture may be related to overall force of impact.

Penetrating Trauma. The position of the gravid uterus frequently prevents maternal visceral injury from penetrating abdominal trauma. The gravid uterus displaces the small bowel into the upper abdominal cavity, protecting it from direct abdominal trauma. However, the bladder is displaced out of the pelvis, increasing its susceptibility to injury. Injury patterns in penetrating trauma include direct fetal injury, placental injury or abruption, and uterine damage leading to preterm delivery. There are also case reports of uterine rupture caused by gunshot.⁵⁴ One study spanning 16 years of civil war in Lebanon showed maternal visceral injuries were present with entrance in the upper abdomen and back and absent if the entrance wound was below the fundus. However, half of cases with penetration below the fundus were associated with fetal demise.⁵⁵ Bullet wounds usually warrant surgical exploration. However, the management is controversial, and some advocate a conservative surgical approach to penetrating wounds, delaying laparotomy.^{25,56}

Preterm Labor. In women who sustain severe trauma early in pregnancy, spontaneous abortions are almost universal. Interestingly, preterm labor or spontaneous abortion has been associated with trauma distant to the gravid uterus.⁴⁴ Trauma presumably results in the release of cytokines, which stimulate uterine contractions. Contractions developed in 28% of pregnant women with major blunt abdominal trauma in the series reported by Williams and colleagues.⁵⁷ Preterm labor leading to preterm delivery is actually very rare, accounting for less than 5% of fetal complications.⁵⁸

If the fetus is viable, tocolysis should be discussed with the obstetrician but is not recommended until placental abruption has been excluded.¹⁴ Even after abruption is excluded, routine med-

Figure 3. Acidosis and Decreased Fetal Heart Rate Variability

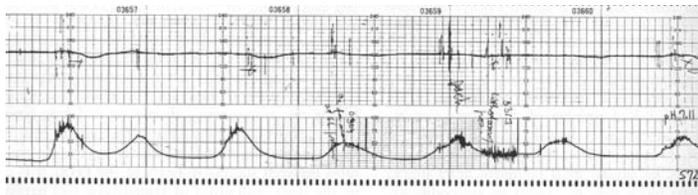


Figure 3. Acidosis with decreased fetal heart rate variability and late decelerations.

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Figure 4. Late Decelerations

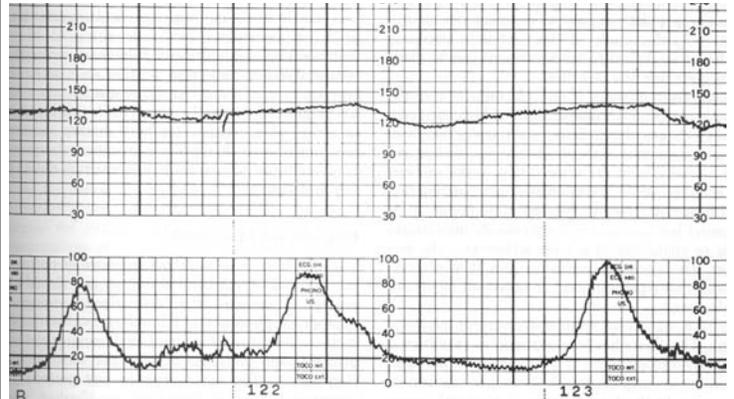


Figure 4. Top: Late decelerations with abruption. Bottom: Corresponding tocometer tracing.

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ications used by obstetricians to treat preterm labor, including magnesium sulfate, terbutaline, and indomethacin, have side effects that may adversely affect the management of the pregnant trauma patient. Magnesium sulfate decreases respiratory effort and at high doses causes hypotension and arrhythmias. Beta-agonists (e.g., terbutaline) cause cardiac stimulation and even hypotension, confounding the evaluation of occult hemorrhage. Indomethacin may be contradicted in patients with head injury or occult bleeding because it affects platelet function.²³

Fractures. Pelvic and acetabular fractures during pregnancy are associated with poorer outcomes than in nonpregnant patients.⁶⁰ Pregnancy predisposes the mother to significant retroperitoneal bleeding due to increased blood flow and severe hypovolemic shock.¹ Currently, there are different modes of managing pregnant patients with pelvic fractures including delayed fixation. Additional research likely will be completed in this area to determine the most successful route of treatment. Pelvic fractures are not an absolute contraindication to vaginal delivery.¹

Disposition

Pregnant trauma patients without significant maternal injuries are not eligible for immediate discharge. Beyond 24 weeks' gestation, at least 4 hours of fetal monitoring is recommended. One study identified gestational age more than 35 weeks, assault, and pedestrian collision as risk factors associated with poor outcomes. Some centers monitor 24 hours, based upon persistently increased risk of fetal complications, including abruption beyond 6 hours, as previously discussed. One study advocates using the emergency observation unit for fetal monitoring if personnel are trained in interpretation of monitors and obstetrics staff is available for consultation.⁶¹ In this case, care providers must be trained in interpretation of monitoring and have direct contact with an obstetrician. In academic centers, patients frequently are transferred to labor and delivery for prolonged monitoring if the acute trauma-related maternal issues have been addressed. If the patient requires ongoing trauma resuscitation unit care or trauma admission, there is variability in fetal monitoring practices. Depending upon gestational age and availability of obstetricians, patients may be monitored on the trauma floor by obstetrics

nurses or followed by the trauma team on an obstetrics unit.

At the time of discharge after fetal monitoring or after maternal evaluation in the previable fetus, it is important to tailor the discharge instructions to the patient. Routine injury-specific discharge instructions should be given. In addition, the patient should follow up with her obstetrician as soon as possible. Patients should be instructed to return to the ED immediately if they experience any change in fetal activity, vaginal bleeding, abdominal pain or contractions, or leakage of fluid.

Special Considerations

Domestic Violence. Emergency care providers must have a high index of suspicion for domestic violence in pregnant trauma patients. Pregnancy is a significant risk factor for abuse, and studies have shown worsening patterns of abuse in pregnancy.⁶² The 1985 National Family Violence Study reported 154 of 1000 pregnant women were assaulted by their partners in the first four months of pregnancy.^{63,64} In addition, studies have established that the frequency of intentional injury sustained during pregnancy is increasing.⁶⁵ Studies have shown that direct interview questioning regarding abuse is the most effective way to identify that abuse is taking place.⁶⁶

During pregnancy, the risk of homicide increases among battered women. A regional study by Krulewitsch showed that maternal mortality resulting from violent death is underreported and thus goes underrecognized.⁶⁷ The gravid abdomen is one of the most common locations of partner-induced trauma. In addition, head and neck, breast, and genital injuries are common.^{14,68}

Many studies have identified associations between domestic violence during pregnancy and adverse pregnancy outcomes. Adverse outcomes include placental abruption, spontaneous abortion, uterine rupture, preterm labor, hemorrhage, and low birth weight.⁶⁹ One study identified an association between com-

plications in pregnancy and physical violence, including partner-inflicted physical harm and being involved in a fight. The prevalence of physical violence in this study was 11.1%.⁷⁰ Overall, studies have shown inconsistent results regarding influence of violence on low birth weight and preterm birth.^{71,72} These studies may be confounded by characteristics that commonly are associated with physical violence and with adverse pregnancy outcome, including young age, poverty, unmarried status, unwanted pregnancy, and substance abuse.⁶⁹ One study concluded that abuse was suspected or known prior to more than half of violent maternal deaths.⁷³ When eliciting a patient's history, it is important to remember the effect of domestic violence on pregnancy and ask questions regarding safety at home. Beyond the current pregnancy, abuse during pregnancy has been associated with future maternal homicide by the abusive partner.⁷⁴ The trauma care provider should be aware of appropriate documentation in suspected or alleged cases of abuse.⁷⁵

Fetomaternal Hemorrhage and RhoGAM. All pregnant trauma patients should have a type and screen performed to determine their Rh antigen status, regardless of gestational age. Despite common beliefs that alloimmunization is rare in the early first trimester, even 38-day-old fetuses have detectable RhD antigen, and at 6 weeks Rh antigen is developed fully.⁷⁶ Minor trauma can be associated with significant fetomaternal hemorrhage. In one study, 28% of minor trauma cases, defined as a stable patient without need for surgery or admission and presenting with only contusions or superficial lacerations, experienced significant hemorrhage.⁷⁷ In trauma patients who are Rh negative, administration of 300 mg of RhoGAM (anti-D immunoglobulin) within 72 hours after onset of fetomaternal hemorrhage will prevent alloimmunization caused by up to 30 mL of Rh-positive fetal blood (15 mL of fetal cells). It has been established that anti-D immunoglobulin should be given to all Rh-negative patients with abdominal trauma.⁷⁸

The Kleihauer-Betke test is used to quantify fetomaternal hemorrhage greater than 0.5 mL. The test has little utility in the acute trauma setting, because maternal fetal hemorrhage volume as low as 0.15 mL has elicited an antigen response; thus, all Rh-negative patients should be considered RhoGAM candidates, even if their Kleihauer-Betke test result is zero. The test can be used by the obstetrician to follow hemorrhage and to determine if additional doses of RhoGAM are indicated.

Medications. Acetaminophen is the only class A medication (i.e., determined safe in pregnant humans by controlled studies). All other medications used in pregnancy are class B (i.e., presumed to be safe, no evidence of risk) or class C (i.e., risk cannot be ruled out). Most medications used in the trauma setting are class B and C medications. Acute trauma-related pain usually is managed with opiates, which cross the placenta freely. Because the fetus absorbs opiates, decreased fetal heart rate variability and decreased fetal movements may be noted. These effects may confound evaluation of fetal well-being. Tetanus immunization is safe during pregnancy.⁷⁹

Antibiotic use in the immediate trauma setting is frequently necessary for the management of open wounds or fractures. A

first-generation cephalosporin often is used in this setting. Briggs and colleagues suggested that teratogenicity can be associated with cefaclor, cephalexin, and cephadrine but not with other cephalosporins.⁸⁰ Other antibiotics considered safe for use in pregnancy should be administered whenever possible. These include older penicillins (e.g., ampicillin and amoxicillin) and macrolides (e.g., erythromycin). Sulfonamides have no documented teratogenic effects;⁸¹ however, they should not be used in the third trimester because of the increased risk of neonatal kernicterus. Antibiotics not recommended for use during pregnancy include the aminoglycosides and tetracyclines.²⁴ An update on the use of antibiotics during pregnancy was published by Niebyl.⁸²

The use of acid-suppressing drugs (e.g., cimetidine, omeprazole, and ranitidine) is considered safe during pregnancy.⁸³

Antiemetic agents safe for use during pregnancy include diphenhydramine (antihistamine) and phenothiazines such as promethazine, prochlorperazine, and thorazine.⁸⁴ Ondansetron has not been evaluated for safety.

In the hypotensive pregnant trauma patient, aggressive crystalloid fluid resuscitation and blood transfusion are the mainstays of therapy. Vasopressors reduce uterine blood flow and should be avoided if possible. If shock is unresponsive to volume resuscitation, ephedrine or dopamine should be considered. Ephedrine classically is used in nontrauma laboring or cesarean-section patients for hypotension without associated uteroplacental insufficiency and with possible increased uterine blood flow during contractions.^{85,86} Low-dose dopamine (up to 5 mcg/kg/min) also has limited effect on placental blood flow, but dopamine at doses greater than 10 mcg/kg/min has been shown to decrease placental blood flow.⁸⁶

Cardiac Arrest and Perimortem Cesarean Section. Cardiac arrest is complicated if the fetus is viable because there are two patients to consider during resuscitative efforts. Advanced cardiac life support should be performed; however, the effectiveness of cardiopulmonary resuscitation (CPR) is limited significantly by the physiologic changes of pregnancy, including decreased stroke volume while in the supine position. CPR also is limited significantly by the required left lateral positioning of the pregnant patient. Uterine evacuation has been shown to increase cardiac output by approximately 60%.⁸⁷ Emergent cesarean delivery of a viable fetus (> 23 weeks' gestation) should be performed after 4 minutes of unsuccessful maternal cardiac resuscitation. CPR should not be stopped to perform the cesarean delivery. The fetus should be delivered within 5 minutes of maternal resuscitation for optimal maternal and neonatal survival rates. There are case reports of delivery of viable infants after delayed perimortem delivery, but the most consistent infant survival rate (up to 70%) relies upon delivery within the first 5 minutes after arrest.⁸⁸

The procedure may be completed within 5 minutes with a large scalpel and hemostats for clamping the umbilical cord. Sterile technique and draping generally are not used because they increase time to delivery. A vertical incision is made from the epigastric region to the symphysis pubis, following the darkened linea nigra. When the uterus has been exposed, a midline vertical uterine incision is initiated at the fundus with the scalpel and

completed with blunt-tipped scissors (e.g., bandage scissors), extending to the bladder reflection. If an anterior placenta is encountered, it should be incised. If the fetus is in the vertex (head-down) position, the operator's hand is placed into the cavity and under the fetal head, drawing it caudad out from the pelvis and through the uterine incision; the body will follow. Then, the umbilical cord should be double clamped and cut and the neonate handed to the team assigned to neonatal resuscitation. At this point, it is important to reassess the mother's vital signs. Delivery usually improves the response to resuscitative efforts significantly.⁸⁹

Conclusion

The management of the pregnant trauma patient is a difficult and complex task and requires coordination between a variety of health care providers, including those in the prehospital, ED, trauma, operating room, and labor and delivery areas.

Several basic principles are paramount in the care of these patients. The first is the concentration of initial evaluation and treatment on maternal injuries; maternal death is the most common cause of trauma-associated fetal death.

The second principle is the importance of involvement of obstetricians and labor and delivery personnel in the care of these patients. This factor is especially important when the stage of fetal viability has been reached.

Finally, domestic violence reaches across our society and is increasing. The pregnant patient is especially at risk, and all health care workers need to be aware and ready to assist the victims of domestic violence and their unborn children.

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CE/CME Objectives

Upon completing this program, the participants will be able to:

- a.) discuss conditions that should increase suspicion for traumatic injuries;
- b.) describe the various modalities used to identify different traumatic conditions;
- c.) cite methods of quickly stabilizing and managing patients; and
- d.) identify possible complications that may occur with traumatic injuries.

CE/CME Instructions

Physicians and nurses participate in this continuing medical education/continuing education program by reading the article, using the provided references for further research, and studying the questions at the end of the article. Participants should select what they believe to be the correct answers, then refer to the list of correct answers to test their knowledge. To clarify confusion surrounding any questions answered incorrectly, please consult the source material. **After completing this activity, you must complete the evaluation form provided and return it in the reply envelope provided in order to receive a certificate of completion.** When your evaluation is received, a certificate will be mailed to you.

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CE/CME Questions

1. What is the most common cause of trauma-associated fetal death?
 - A. Fetal brain trauma
 - B. Fetal spinal fracture
 - C. Maternal death
 2. Patients in the third trimester of pregnancy should be transported to the hospital in the left lateral tilt position. The benefit of this position is:
 - A. Improved functional residual capacity
 - B. Increased comfort for the patient
 - C. Prevention of aortocaval compression
 3. Examination of a pregnant patient's abdomen reveals a fundal height at the level of the umbilicus. What is the estimated gestational age?
 - A. 16 weeks
 - B. 20 weeks
 - C. 24 weeks
 4. Serial examinations of fundal height performed on a pregnant patient reveal a rising fundus. This finding indicates which of the following conditions?
 - A. Concealed placental abruption
 - B. Placenta previa
 - C. Preterm labor
 5. Which complication of traumatic injury in the pregnant patient is associated with 100% fetal mortality?
 - A. Placental abruption
 - B. Placenta previa
 - C. Uterine rupture
 6. The most effective way to identify that a pregnant woman is a victim of domestic violence is:
 - A. Direct interview questioning
 - B. Fetal monitoring
 - C. Physical examination
 7. A pregnant patient with abdominal trauma should be given RhoGAM if:
 - A. she is Rh negative and in any stage of pregnancy.
 - B. she is Rh negative and in the second trimester or later.
 - C. she is Rh negative and in the third trimester.
 8. Which of the following regarding placental abruption is true?
 - A. It is not associated with minor trauma.
 - B. It never occurs more than 6 hours after trauma.
 - C. It is the most common cause of fetal demise after blunt abdominal trauma.
 9. The goal during postmortem cesarean section is to deliver the fetus within how many minutes after maternal arrest?
 - A. 5 minutes
 - B. 10 minutes
 - C. 15 minutes
 10. In a pregnant patient with vaginal bleeding, what test can determine if the blood is fetal or maternal in origin?
 - A. Apt test
 - B. Ferning test
 - C. Fetal DEX test
- Answers** 1. C; 2. C; 3. B; 4. A; 5. C; 6. A; 7. A; 8. C; 9. A; 10. A

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The objectives of *Trauma Reports* are to:

1. Discuss conditions that should increase suspicion for traumatic injuries;
2. Describe the various modalities used to identify different traumatic conditions;
3. Cite methods of quickly stabilizing and managing patients; and
4. Identify possible complications that may occur with traumatic injuries.

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Sincerely,

A handwritten signature in black ink that reads "Brenda L. Mooney". The signature is written in a cursive, flowing style.

Vice-President/Group Publisher
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