Trauma in Pregnancy

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KEY CONCEPTS

- Female trauma patients of reproductive potential should be screened for pregnancy and assumed to be pregnant until proven otherwise.
- Management of life- and limb-threatening injury in the mother comes first. Saving the mother provides the best chance of saving the baby.
- Even in the stable pregnant trauma patient, the fetus is at increased risk of morbidity and mortality; therefore, the fetus should be monitored by cardiotocography continuously for a minimum of 4 hours after any trauma.
- The fetus is considered viable between 22 to 24 weeks' gestation (>500 grams). This usually corresponds to when the fundus is at or above the umbilicus.
- Alterations in anatomy and physiology that occur during pregnancy alter the pattern of injuries in trauma and the clinical findings related to blood loss, which may mask injuries, making a systematic approach essential.
- Keeping the mother tilted 15 to 30 degrees to the left, or manually displacing the uterus leftward, in any pregnancy of 20 weeks' gestation or greater is recommended to alleviate hypotension due to aortocaval compression in order to improve maternal and fetal perfusion.
- Resuscitative hysterotomy should be initiated for a potentially viable fetus (fundus above the umbilicus) within 4 minutes and completed in 5 minutes after the onset of cardiopulmonary arrest and no return of spontaneous circulation (ROSC) for optimal maternal and fetal benefits.
- The use of ionizing radiation to the pregnant patient, including CT and plain radiography, should be minimized, but imaging should not be withheld if it may provide significant diagnostic information. In certain circumstances ultrasound, MRI, or a period of observation can preclude the need for ionizing radiation.

FOUNDATIONS

Trauma, both intentional and unintentional, occurs in up to 8% of all pregnancies and is the leading nonobstetric cause of maternal death.[1-3] The most common causes of injury in pregnancy are motor vehicle collisions (MVCs), interpersonal violence, and falls. Trauma in pregnancy increases the risk of spontaneous abortion, preterm rupture of membranes, preterm birth, uterine rupture, cesarean delivery, placental abruption, and stillbirth. Because some woman are not aware they are pregnant when they present to a trauma center, all women of reproductive potential should be screened for pregnancy.

Commonly used thresholds of fetal viability are an estimated gestational age between 22 and 24 weeks or an estimated fetal weight of 500 gr. Only viable fetuses are monitored, because no obstetric intervention will alter the outcome with a previable fetus. Counseling on proper seatbelt and alcohol/drug use as well as screening for interpersonal violence may help to reduce the morbidity and mortality rates for pregnant patients.[4] Although the essential principles of trauma management remain unchanged in the pregnant patient, there are special considerations in the management of these patients due to the gravid uterus altering the pattern of injury, and changes in physiology and anatomy that affect multiple organ systems. Although there are two lives involved, maternal life takes priority and fetal outcomes are directly correlated with early and rapid maternal resuscitation.[5]

Anatomic Changes in Pregnancy

The uterus remains an intrapelvic organ until approximately the 12th week of gestation. It reaches the umbilicus by 20 weeks and the costal margins by 34 to 36 weeks. At term, the uterus has often enlarged by 30 cm and has increased fifteen-fold in weight, which alters the normal anatomic location and function of multiple structures. The diaphragm progressively rises in pregnancy with compensatory flaring of the ribs, which may predispose to pneumothorax and a faster progression to tension pneumothorax. A thoracostomy done in the third trimester requires that the chest tube be placed one or two interspaces higher than the usual fifth interspace site to allow for diaphragm elevation.[6]

Abdominal viscera are pushed upward by the enlarging uterus and can alter the location of perceived pain. The gravid uterus itself tends to protect abdominal organs from trauma but substantially increases the likelihood of bowel injury from penetrating trauma to the upper abdomen. Conversely, the upward displacement of the bowel makes it less susceptible to blunt trauma. The stretching of the abdominal wall as pregnancy nears term modifies the normal response to peritoneal irritation (blunting of muscle guarding and rebound), potentially underestimating the extent and severity of maternal trauma despite intra-abdominal bleeding and organ injury.

In the first trimester, the bony pelvis shields the uterus and bladder. After the third month, these structures rise out of the pelvis and become vulnerable to direct injury. Both organs become hyperemic during pregnancy, and injury may lead to a marked increase in blood loss compared with similar injury in a nonpregnant patient. Ureteral dilation secondary to smooth muscle relaxation or from compression by the gravid uterus is often found on imaging studies but is not necessarily pathologic. The ligaments of the symphysis pubis and sacroiliac joints are loosened during pregnancy. As a result, a baseline diastasis of the pubic symphysis may exist that can be mistaken for pelvic disruption on radiographic studies.

Physiologic Changes

Cardiovascular

The normal cardiovascular changes of pregnancy can alter the clinical presentation and may either mimic or mask the recognition of shock or exacerbate the effects of traumatic hemorrhage (Table 177.1). Blood pressure declines in the first trimester, levels out in the second trimester, and then returns to nonpregnant levels during the third trimester. The decline in systole is small, 2 to 4 mm Hg, whereas diastole falls 5 to 15 mm Hg. Heart rate increases in pregnancy but does not rise by more than 10 to 15 beats per minute above baseline (mean of approximately 90 beats/min).

TABLE 177.1 Hemodynamic Changes of Pregnancy (Mean Values)

Parameter	Nonpregnant	Trimester 1	Trimester 2	Trimester 3
Heart rate (beats/min)	70	78	82	85
Systolic blood pressure (mm Hg)	115	112	112	114
Diastolic blood pressure (mm Hg)	70	60	63	70
Cardiac output (L/min)	4.5	4.5	6	6
Central venous pressure (mm Hg)	9.0	7.5	4.0	3.8
Blood volume (mL)	4000	4200	5000	5600
Hematocrit without iron (%)	40	36	33	34
Hematocrit with iron (%)	40	36	34	36
White blood cells (cells/mm^3)	7200	9100	9700	9800

Data from: de Swiet M. The cardiovascular system. In: Hytten F, Chamberlain G, eds. *Clinical Physiology in Obstetrics*. Oxford: Blackwell Scientific Publications; 1980: 3-42; Colditz RB, Josey WE. Central venous pressure in supine position during normal pregnancy. Comparative determinations during first, second and third trimesters. *Obstet Gynecol*. 1970;36:769; Letsky E. The haematological system. In: Hytten RF, Chamberlin G, eds. *Clinical Physiology in Obstetrics*. Oxford: Blackwell Scientific Publications; 1980: 43-78; and Cruikshank DP. Anatomic and physiologic alterations of pregnancy that modify the response to trauma. In: Buchsbaum HJ, ed. *Trauma in Pregnancy*. Philadelphia: WB Saunders; 1979: 21-39.

A major contributor to maternal hypotension is the supine hypotensive syndrome. After 20 weeks' gestation, the enlarging uterus has risen to the level of the inferior vena cava, resulting in compression when the mother is supine. Aortocaval obstruction diminishes cardiac preload, which can decrease cardiac output and systolic blood pressure. In late pregnancy, it is common for the inferior vena cava to become completely occluded when the pregnant patient is supine. Hemodynamic improvement occurs when compression is relieved. In determining whether observed hypotension is related to positioning, the pregnant woman can be tilted 15 to 30 degrees onto her left side, or if unable due to injuries, the uterus can be manually displaced to the left by using two hands in order to relieve compression on the inferior vena cava. Elevating the patient's legs will improve venous return. Inferior vena caval compression can also lower central venous pressure (CVP) in the last two trimesters.

Blood volume gradually increases during pregnancy, starting at 6 to 8 weeks' gestation, to as much as 45% above normal, peaking at 32 to 34 weeks' gestation. Blood volumes become increasingly larger for multigravidas and for twin, triplet, and quadruplet gestations. With this increased circulatory reserve, clinical signs of maternal hypotension from acute traumatic bleeding may be delayed. Up to 35% of circulating blood volume may be lost before an injured pregnant patient exhibits signs or symptoms of shock.[5] By the beginning of the second trimester and throughout the remainder of pregnancy, cardiac output is increased 40% to 6 L/min. Blood flow to the uterus increases from 60 mL/min before pregnancy to 600 mL/min at term. This hyperdynamic state is needed to maintain adequate oxygen delivery to the fetus. Because the mother's total circulating blood volume flows through the uterus every 8 to 11 minutes at term, this can be a major source of blood loss in injury.

By the third trimester, there is also marked venous congestion in the pelvis and lower extremities, increasing the potential for hemorrhage from both bony and soft tissue pelvic injuries. Compression of the lower abdominal venous system by the gravid uterus increases peripheral venous pressure and blood volume in the legs, creating the potential for brisk blood loss from leg wounds and can exacerbate bleeding from attempts at central venous catheter placement.

Pulmonary

The pregnant woman at term has a reduced oxygen reserve due to a reduction in functional residual capacity caused by diaphragm elevation and an increase in oxygen consumption related to the growing fetus, uterus, and placenta. Mean arterial oxygen tension drops by 29% in pregnant women at term during 60 seconds of apnea compared with 11% in nonpregnant women. Labor further accelerates this decline. In addition, minute ventilation and tidal volume increase, leading to hypocapnia. Therefore, a partial pressure of carbon dioxide in the arterial blood ($Paco_2$) of 35 to 40 mm Hg may indicate inadequate ventilation and impending respiratory decompensation in the pregnant patient. Maternal hypoxia rapidly leads to fetal hypoxia, distress, and possibly demise. There are no contraindications to rapid sequence intubation during pregnancy. Bag-valve-mask ventilation is more difficult in the pregnant patient due to weight gain and obesity. The incidence of difficult or failed intubations in obstetric anesthesia is four times higher than in surgical nonobstetric patients. Pregnant patients are considered difficult airways with potential for rapid desaturation due to decreased oxygen reserves, increased oxygen demands, upper airway edema, mucosal friability, increased Mallampati scores with increasing gestational age, and increased risk of aspiration. It is recommended that the emergency clinician use a difficult airway algorithm, prepare equipment in advance including rescue devices, call for help early if available, and optimize a ramped, head up, or reverse Trendelenburg position to optimize preoxygenation and apneic oxygenation in all pregnant patients.

Gastrointestinal

Gastroesophageal sphincter tone and gastrointestinal motility are decreased in pregnancy, thus increasing the possibility of aspiration in patients with altered level of consciousness, such as during intubation. Early gastric decompression should be performed in these circumstances.

SPECIFIC DISORDERS

Blunt Trauma

Physical examination is unreliable in predicting adverse outcomes in the pregnant woman with blunt trauma.[7] Risk factors predictive of the onset of contractions or preterm labor include gestational age greater than 35 weeks, assaults, and pedestrian collisions. Fetal mortality can be as high as 40% after maternal trauma, with most likely causes of fetal

death occurring from placental abruption, maternal shock, and maternal death, in order of decreasing incidence. Risk factors significantly predictive of fetal death include ejection, motorcycle and pedestrian collisions, maternal death, maternal tachycardia, abnormal fetal heart rate, lack of restraints, and an injury severity score greater than 9 (see Chapter 32).

Unbelted or improperly restrained pregnant women are twice as likely to experience excessive maternal bleeding and increased maternal death with fetal death being three times more likely to occur. For low- to moderate-severity collisions (constituting 95% of all MVCs), proper restraint use, with or without air bag deployment, generally leads to acceptable fetal outcomes. For high-severity collisions, even proper restraint does not improve fetal outcome.

Pregnant crash-test-dummy trials show that improper placement of the lap belt over the pregnant abdomen causes a threefold to fourfold increase in force transmission through the uterus. The lowest force transmission readings through the uterus occur when a three-point seat belt is used properly. For correct position, the lap belt should be placed under the gravid abdomen, snugly over the thighs, with the shoulder harness off to the side of the uterus, between the breasts and over the midline of the clavicle. Women who receive information on seat belt use during pregnancy from a health care provider are statistically more likely to use seat belts and to use them properly than uninformed controls.

Interpersonal Violence

Women experiencing abuse in the year before or during a pregnancy are 40% to 60% more likely than nonabused women to report high blood pressure, vaginal bleeding, severe nausea, kidney or urinary tract infections, and hospitalization during that pregnancy.[4] Abused pregnant women are more likely to deliver preterm, and children of abused pregnant women are more likely to be born underweight. Children born to abused mothers are more likely than other children to require intensive care at birth. Physicians detect only a minority of interpersonal violence cases in pregnant women, which supports the need for routine screening for interpersonal violence in this population.[4]

Falls

Falls become more prevalent after the 20th week of pregnancy and roughly 25% of pregnant women will fall at least once while pregnant. Protuberance of the abdomen, loosening of pelvic ligaments, strain on the lower back, and fatigability are contributory factors. In a given pregnancy, about 2% of pregnant women sustain repeated direct blows to the abdomen from repetitive falls. Although repeated falls often trigger premature contractions, they seldom result in immediate labor and delivery.

Penetrating Trauma

The gravid uterus affects the injury pattern seen with penetrating trauma to the upper abdomen with the probability of harm to the bowel, liver, or spleen at almost 100%. When the entry site is anterior and below the uterine fundus, visceral injuries are less likely. Although the enlarging uterus can act as a shield against intra-abdominal injuries in the mother, it makes the fetus more susceptible to injury. A high fetal death rate from penetrating trauma to the uterus has been reported and is lower for maternal injuries above the uterus.

Fetal Injury

There is a high risk of fetal loss in the pregnant trauma patient. Poor fetal outcome is predicted by maternal hypotension and acidosis, and a fetal heart rate less than 110 beats/min. When the mother sustains life-threatening injuries, there is a 40% chance of fetal demise, compared with a less than 2% chance in cases of non–life-threatening maternal injuries. Disseminated intravascular coagulation (DIC), which may be caused by placental products entering the maternal circulation, is a significant predictor of fetal mortality. The American College of Obstetrics and Gynecology recommends a minimum of 4 hours of cardiotocographic fetal monitoring after maternal trauma because monitoring is useful in predicting fetal outcome.

Fatal fetal injuries from blunt trauma are usually the result of intracranial hemorrhage and skull fractures secondary to fractured maternal pelvic bones striking the fetal skull as a result of vertex lie.[8] Pelvic and acetabular fractures during pregnancy are associated with a high maternal (9%) and a higher fetal (38%) mortality rate. Both gunshot wounds and stab wounds to the uterus produce substantial morbidity and mortality to the fetus.

Placental Injury

The leading cause of fetal death after blunt trauma is placental abruption.[1] Placental separation results when the inelastic placenta shears away from the elastic uterus during sudden deformation of the uterus. Because deceleration forces can be as damaging to the placenta as direct uterine trauma, abruption can occur with little or no external sign of injury to the abdominal wall. Placental abruption inhibits the flow of oxygen to the fetus and causes in utero carbon dioxide (CO_2) accumulation, resulting in hypoxia and acidosis that leads to fetal distress. Sustained uterine contractions induced by intrauterine hemorrhage also inhibit uterine blood flow, further contributing to fetal hypoxia.

The diagnosis of abruption is made clinically. Classic clinical findings of abruption are vaginal bleeding, abdominal cramps, uterine tenderness, maternal hypovolemia (up to 2 L of blood can accumulate in the gravid uterus), or a change in the fetal heart rate; but many cases of placental abruption after trauma present without vaginal bleeding.

The most sensitive indicator of placental abruption is fetal distress, which can be detected with prompt fetal monitoring. In clinical settings without continuous fetal monitoring capabilities intermittent monitoring of FHR (e.g., every 15 minutes) is recommended, but early transfer should be arranged to a facility with obstetric and neonatal services as the definitive treatment may be surgical. Increased frequency of contractions is associated with abruption. Transabdominal ultrasonography has poor sensitivity for detection of placental abruption (24% sensitivity; 96% specificity).[9] Placental abruption hematomas have a variable appearance on ultrasound including homogenous and heterogenous consistency, and can be either hypo-, hyper-, or isoechoic compared to the placenta depending on the extent and chronicity of bleeding. If the abruption bleeds externally, there may be an insufficient quantity to be detected sonographically. Even with significant intrauterine blood accumulation, accurate ultrasonographic diagnosis may be difficult because of placental position (i.e., posterior) and confounding uterine or placental structural conditions. An ultrasound is useful in clinical practice despite the poor sensitivity because it can help identify other causes of abdominal pain or vaginal bleeding in the setting of trauma.

Placental abruption is associated with an increased risk of stillbirth (after 20 weeks) and preterm delivery (before 37 weeks) even with minor abruption. The extent of placental separation is correlated with the rate of stillbirth. A trial of expectant management with ongoing maternal and fetal monitoring is appropriate when mother and fetus are stable and with partial placental abruptions of less than 25%. This usually applies to fetuses of less than 32 weeks' gestation in which the likelihood of morbidity and mortality associated with prematurity makes delivery management risky. Expectant care in stable patients may allow further fetal maturation and improved outcome. An immediate cesarean section is recommended in cases of fetal distress from

further placental separation. After 32 weeks' gestation, the risk of further placental separation outweighs the benefits of further fetal maturation, so intervention is indicated.

Women with placental abruption are more likely to have coagulopathies than those without abruption. The injured placenta can release thromboplastin into the maternal circulation, resulting in DIC, whereas the damaged uterus can disperse plasminogen activator and trigger fibrinolysis. The precipitation of DIC is directly related to the degree of placental separation. Severe clotting disorders rarely occur unless separation of the placenta is significant enough to result in fetal demise.

Uterine Injury

The most common obstetric complication caused by maternal trauma is uterine contractions. Myometrial and decidual cells, irritated by contusion or placental separation, release prostaglandins that stimulate uterine contractions. Progression to labor depends on the extent of uterine damage, the amount of prostaglandins released, and the gestational age of the pregnancy. The routine use of tocolytics for preterm labor is not recommended because most contractions stop spontaneously. Contractions that are not self-limited are often induced by some pathologic condition, such as underlying placental abruption, which is a contraindication to tocolytic therapy. Some studies describe this risk as relative and have used tocolysis successfully with careful evaluation and intensive monitoring to continue the pregnancy and enhance fetal maturity. The option to use tocolytics ends when cervical dilation reaches 4 cm or greater.

Traumatic uterine rupture is a rare event. It is most often caused by severe vehicular collisions in which pelvic fractures strike directly against the uterus. Uterine rupture may occur from stab wounds and gunshot injuries, but this is rare. Maternal shock, abdominal pain, easily palpable fetal anatomy caused by extrusion into the abdomen, and fetal demise are typical findings on examination. Diagnosing uterine rupture can be difficult. A fractured liver or spleen can produce similar signs and symptoms of peritoneal irritation, hemoperitoneum, and unstable vital signs. Optimal treatment, between suturing the tear or performing a hysterectomy, depends on the extent of uterus and uterine vessel tears and the importance of future childbearing.

DIAGNOSTIC TESTING

All women of childbearing potential presenting with trauma should be assessed for possible pregnancy.

Changes in Laboratory Values with Pregnancy

Increases in plasma volume greater than red blood cells cause a physiologic anemia of pregnancy (hematocrit 32% to 34% by the 32nd to 34th week). Despite the lower hematocrit, there is an overall increase in oxygen-carrying capacity because of an increased total red blood cell mass. Placental progesterone directly stimulates the medullary respiratory center, producing a lower $Paco_2$ (30 mm Hg) from the second trimester until term. The subsequent compensatory lowering of serum bicarbonate slightly reduces blood-buffering capacity during conditions of physiologic stress. A $Paco_2$ of 40 mm Hg in the latter half of pregnancy reflects inadequate ventilation and potential respiratory acidosis that could precipitate fetal distress.

Electrocardiographic changes include a left-axis shift averaging 15 degrees, caused by diaphragm elevation. Consequently, flattened T waves or Q waves in leads III and augmented voltage unipolar left limb lead may be seen (Fig. 177.1)

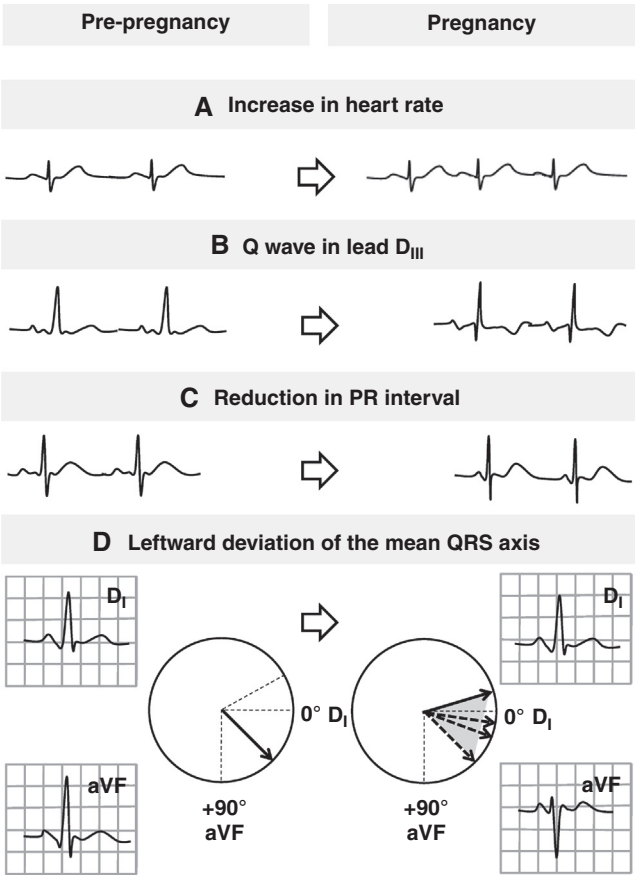

Fig. 177.1 EKG changes in pregnancy. (From: Angeli F, Angeli E, Verdecchia P. *Int J Mol Sci.* 2015;16(8):18454-18473; https://doi.org/10.3390/ijms160818454.)

Laboratory

Laboratory tests for a pregnant patient with trauma should include a complete blood count, basic electrolyte panel, urinalysis, blood type with Rh status, and coagulation studies including fibrinogen.[6] Patients who appear to be stable but have a low serum bicarbonate level may have occult maternal shock. Interpretation of bicarbonate results requires consideration of the physiologic changes that occur in the later stages of pregnancy as a result of respiratory alkalosis (see Chapter 173). Coagulation studies are important in directing management of patients with multisystem trauma or when the diagnosis of placental abruption is considered.

Kleihauer-Betke Test and Fetomaternal Hemorrhage

Fetomaternal hemorrhage (FMH), the transplacental bleeding of fetal blood into the normally separate maternal circulation, is a unique complication of pregnancy. MVCs, anterior placental location, and uterine tenderness are associated with an increased risk of FMH. Massive fetomaternal transplacental hemorrhage causes alloimmunization in Rh incompatibility but also endangers the fetus by causing severe fetal anemia, fetal distress, and possible exsanguination. ABO incompatibility causes less severe disease.

FMH most commonly occurs after 12 weeks' gestation, when the uterus rises above the pelvis and becomes susceptible to direct trauma.

The Kleihauer-Betke test quantifies the amount of FMH. Most laboratories screen for FMH of 5 mL or more, even though the amount of FMH sufficient to sensitize most Rh-negative women is much less than 5 mL. Therefore, it is advisable that all Rh-negative mothers who have a history of abdominal trauma receive one prophylactic dose of Rhesus immune globulin

(RhIG) within 72 hours of injury. Trauma patients at risk for massive FMH will have major injuries or abnormal obstetric findings, such as uterine tenderness, contractions, or vaginal bleeding. Rarely, the amount of FMH will exceed that covered by the maximum RhIG dose (300 μg). Because RhIG can effectively prevent Rh isoimmunization when administered as late as 72 hours after antigenic exposure, the results of the Kleihauer-Betke test are not immediately needed in the emergency department (ED).

Radiography

Adverse effects to the fetus are unlikely if radiation exposure is less than 50 mGy. Less than 1% of trauma patients are exposed to more than 30 mGy. Sensitivity to radiation is greatest during intrauterine development when the embryo undergoes organogenesis in weeks 2 to 15. However, the risk to the fetus of a 10-mGy exposure is thousands of times smaller than the spontaneous risks of malformations, abortions, or genetic disease. Intrauterine exposure to 50 mGy does not appear to cause a significant increase in congenital malformations, intrauterine growth retardation, or miscarriage but is associated with a 0.3% increased risk of childhood cancer and 2% risk of lifetime cancer. Pathologic conditions more readily appear with intrauterine radiation doses of 150 mGy or greater.

Providing information on radiation exposure from diagnostic radiographs is difficult. Fetal dose from computed tomography (CT) scans depends on the type of equipment used, the abdominal girth of the mother, and the fetal distance from the maternal skin. Diagnostic radiographic studies should be performed with regard for fetal protection, but necessary diagnostic studies of the traumatized pregnant patient should not be withheld out of concern for fetal radiation exposure.[10] Fetal irradiation should be minimized by limiting the scope of the examination and using technical means, such as shielding and collimation. Table 177.2 provides estimated radiation doses from various types of examinations.

Ultrasonography

Ultrasonography is the best modality for simultaneous assessment of the mother and fetus. It is useful in detecting major abdominal injury and establishing fetal well-being or demise, gestational age, and placental location. It obviates radiation risks, minimizes diagnostic delays, and provides high sensitivity for injury. The sensitivity of the focused assessment with sonography for trauma (FAST) examination in identifying intra-abdominal bleeding or pericardial bleeding is 61% to 83%, lower than the general population, but it has a specificity and negative predictive value of 99.7%.[11] Ultrasonography has low sensitivity (24%) but high specificity (96%) for placental abruption.[9] Limitations in accuracy include operator experience, patient obesity, the presence of subcutaneous air, and a history of multiple abdominal surgeries.[11]

Computed Tomography and Magnetic Resonance Imaging Scans

CT and, increasingly, magnetic resonance imaging (MRI) studies are used in evaluating abdominal trauma in pregnancy.[6] If ultrasonography is indeterminate and the patient's condition is stable, CT and MRI can identify specific organ damage. They are particularly useful in assessing penetrating wounds of the flank and back. CT can miss diaphragm and bowel injuries. Both of these studies carry the risk of moving the patient from the closely monitored environment of the ED to the radiography suite.

Radiation from CT is a concern in the pregnant trauma patient. However, with shielding, fetal exposure from head and chest CT scans can be kept below an acceptable 1-rad limit. CT of the abdomen can be performed with 4 mGy of exposure to the fetus. Abdomen and pelvic CT produces about 25 mGy of radiation to the fetus, which is well below the 50 mGy level, where a 2% increase in risk of cancer is seen without evidence of malformation to the fetus. Radiation exposure ultimately depends on the patient, scanner, and technique used in performing the study (see Table 177.2).

When available, MRI is preferable to CT because it uses no radiation and has not been associated with significant fetal disease or disability, and it is more sensitive in diagnosing diaphragm and bowel injury.

TABLE 177.2 Estimated Fetal Radiation Dose From Conventional Radiographic and Computed Tomography Examination[21,22]

Imaging Study	Estimated Fetal Dose (mGy)[a]
Radiography	
Cervical spine (AP, lateral)	<0.001
Extremities	<0.001
Chest (PA, lateral)	0.0005–0.01
Thoracic spine	0.003
Abdomen (AP)	0.1–3.0
Lumbar spine (AP, lateral)	1–10
Computed Tomography	
Head or neck	0.001–0.01
Chest (routine)	0.01–0.66
Chest (pulmonary embolism protocol)	0.01–0.66
Abdomen	1.3–35
Pelvis	10–50
Abdomen and pelvis	13–25
CT angiography of the aorta	6.7–56
CT angiography of the coronary arteries	0.1–3
Nuclear Medicine	
Low-dose perfusion scintigraphy	0.1–0.5
V/Q scintigraphy	0.1–0.8
Myocardial perfusion with 99mTc-sestamibi	17
Myocardial perfusion with 99mTc-tetrofosmin	8.45

[a]The naturally occurring background radiation dose during pregnancy is 0.5 to 0.1 mGy.

AP, Anteroposterior; *CT,* computed tomography; *PA,* posteroanterior.

Data adapted from: Trada N, Dreizin D, et al. Imaging pregnant and lactating patients. *Radiographics.* 2015;35(6):1751-1765; Copel J, et al. Guidelines for diagnostic imaging during pregnancy and lactation. ACOG committee opinion number 723. *Obstet Gynecol.* 2017;130:e210-216.

SPECIAL PROCEDURES

Diagnostic Peritoneal Lavage

In unstable trauma patients with equivocal or negative findings on ultrasonography, diagnostic peritoneal lavage (DPL) may be considered in any trimester. It should be performed in conjunction with a trauma surgeon using an open technique above the uterus following placement of a nasogastric tube and Foley catheter. The gravid uterus, in the later trimesters, makes the procedure riskier and technically challenging.

MANAGEMENT

Management of the patient with multiple trauma is covered in Chapter 32. The following discussion focuses on the aspects of management unique to the pregnant patient.

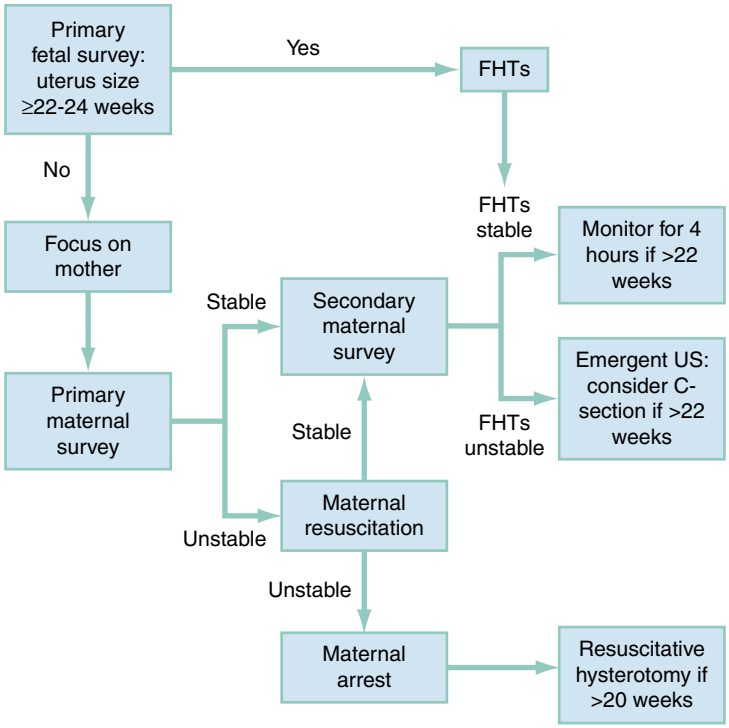

Fig. 177.2 Decision-making algorithm in emergency obstetric care. *C-section,* Cesarean section; *FHT,* fetal heart tone; *US,* ultrasonography.

Depending on the mechanism of trauma, maternal condition, and gestational age, the clinician should consider early notification or consultation with a trauma surgeon, obstetrician, neonatologist, or pediatrician (or all four) for a multidisciplinary approach. A fetal monitor, portable ultrasound, and neonatal resuscitation equipment should be immediately available. Tetanus toxoid and immune globulin have no detrimental effect on the fetus. The World Health Organization (WHO) specifically recommends vaccination during pregnancy. To prevent alloimmunization of a Rh-negative mother, administer one 50-µg dose of RhIG in the first trimester. It is sufficient because total fetal blood volume is only 4.2 mL by 12 weeks' gestation, and a 50 µg-dose covers 5 mL of bleeding. During the second and third trimesters, a 300-µg dose of RhIG is given, which protects against up to 30 mL of FMH. Beyond 16 weeks' gestation, the total fetal blood volume reaches 30 mL or more. Massive FMH likely exceeds the efficacy of one 300-µg dose of RhIG, so the Kleihauer-Betke test can be used to guide effective dosing.

Maternal Resuscitation

Primary Survey

The primary survey focuses on the mother. However, because two patients are present, it is reasonable to gather preliminary information about the age of the fetus at this time (Fig. 177.2).

Airway and Breathing. The general principles of airway management are discussed in Chapter 1. Oxygen therapy should be instituted early in the traumatized pregnant patient because she can quickly become hypoxic due to her reduced oxygen reserve and increased oxygen consumption. The fetus is vulnerable to any reduction in oxygen delivery. Supplemental oxygen is recommended throughout maternal resuscitation and evaluation with oxygenation saturation levels maintained above 95%.[6]

A secure airway enables proper oxygenation and negates the higher risk of aspiration in pregnancy. Rapid sequence intubation after preoxygenation of the pregnant patient is recommended. Data are limited on use of RSI agents during pregnancy but none have been consistently associated with congenital malformations or adverse effects on the fetus. Mechanical ventilation settings need to be adjusted for increased tidal volumes and respiratory alkalosis, which is consistent with the physiologic $Paco_2$ of 30 mm Hg in the last stage of pregnancy. No specific initial ventilation settings are recommended, but settings can be adjusted as clinically indicated and if the patient has ARDS clinicians can use the ARDS network guidelines.[12]

Circulation. Intravenous access with two large-bore catheters above the diaphragm is preferred. Maternal blood pressure and heart rate are not consistently reliable predictors of fetal and maternal hemodynamic stability. Due to an expanded circulating volume, the mother can hemorrhage without showing early signs of hypotension. Uterine blood flow is markedly reduced when maternal circulation is compromised. As a result, after an acute blood loss, uterine blood flow can be substantially decreased while maternal blood pressure remains normal. Consequently, the pregnant woman with borderline hemodynamic stability probably already has a jeopardized fetus. When traditional signs of shock appear, fetal compromise may be far advanced.

Fluid resuscitation with isotonic fluids should occur in all patients with suspected or observed significant blood loss. Type O-negative packed red blood cells are recommended for hemodynamically unstable trauma patients until type-specific blood products are available. Vasopressors are recommended only with refractory hypotension unresponsive to fluid resuscitation because of the adverse effect on uteroplacental perfusion.[6] A massive transfusion protocol should be initiated on all hemodynamically unstable patients in a 1 : 1 : 1 ratio of red blood cells, platelets, and plasma. Tranexamic acid is an antifibrinolytic agent used in trauma to reduce bleeding and mortality and should be administered within 3 hours of injury. Limited data are available on the safety of tranexamic acid in pregnancy but no adverse fetal events have been described. It is unknown if there is a mortality benefit with the use of tranexamic acid in pregnant trauma patients.[1,13]

Beyond 20 weeks' gestation, a left lateral tilt of 15 to 30 degrees or leftward manual displacement of the uterus using two hands is

recommended to reduce compression on the inferior vena cava caused by the gravid uterus. A Foley catheter for measuring urine output provides further information on circulatory volume status.

With trauma in pregnancy, the primary survey is modified to assess uterine size and the presence of fetal heart tones if the patient is severely injured. Otherwise, this assessment belongs in the secondary survey. Uterine size, measured from the symphysis pubis to the fundus, is the quickest means of estimating gestational age. This distance in centimeters equals the gestational age in weeks (e.g., 24 cm = 24 weeks), which allows some early indication of fetal viability if delivery is necessary (Fig. 177.3). Usually, between 22 to 24 weeks is used as the cutoff point for fetal viability (Table 177.3). As a rough guide, the fetus is potentially viable when the dome of the uterus extends beyond the umbilicus. Fetal heart tones can be detected by auscultation at 20 weeks' gestation or by Doppler probe at 10 to 14 weeks. If either the uterus is less than 22 cm in size or fetal heart tones are absent, the pregnancy is probably too early to be viable, and treatment is directed solely at the mother.

Secondary Survey

The secondary survey involves a detailed examination of the patient but is also modified to gather additional information about the maternal abdomen and the fetus. Physical examination of the abdomen, frequently unreliable in the nonpregnant patient, is even more inaccurate with changing organ position, abdominal wall stretching in advancing pregnancy, and uterine contraction pains. Still, valuable information can be gathered about uterine tenderness, contraction frequency, and vaginal bleeding.

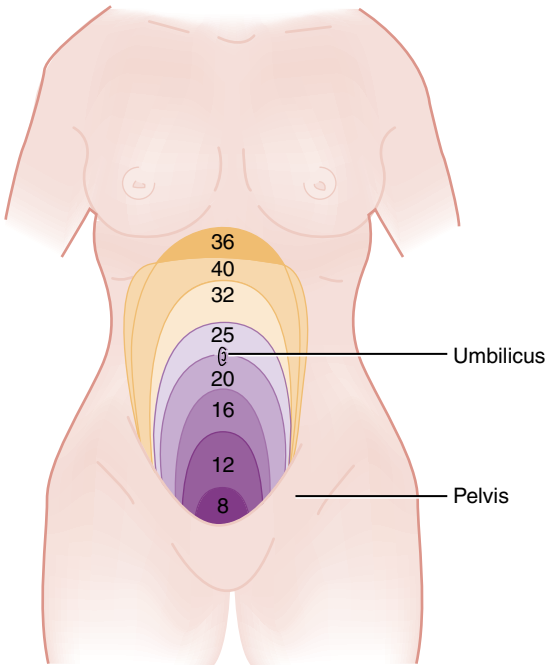

Fig. 177.3 Uterine size at different weeks of gestation. (From: Kravis TC, Warner CG, eds. *Emergency Medicine: A Comprehensive Review*. Rockville, MD: Aspen Publishers; 1979.)

An external perineal examination should be performed. A sterile speculum examination is done in consultation with or by an obstetrician after placental previa has been ruled out by ultrasonography. A bimanual examination is avoided due to the risk of causing prelabor rupture of membranes or bleeding in cases of unidentified placenta previa. Vaginal bleeding suggests placental abruption, and a watery discharge suggests rupture of the membranes. Significant vaginal bleeding from intravaginal injuries can be temporized by packing with sterile moistened gauze. If the mechanism of injury is significant enough and the fetus is judged to be viable, early involvement of an obstetrician may enhance the fetal outcome.

Fetal Evaluation. Fetal evaluation in the secondary survey focuses on the fetal heart rate and detection of fetal movement. When the presence of fetal heart tones has been confirmed, intermittent monitoring of fetal heart rate is sufficient for the previable fetus. If the fetus is viable (i.e., 22 to 24 weeks or more), continuous external monitoring initiated quickly and maintained throughout all diagnostic and therapeutic procedures may be useful in directing management. Such monitoring can also benefit the mother, because fetal hemodynamics are more sensitive to decreases in maternal blood flow and oxygenation than are most measures of the mother. Fetal distress can be a sign of occult maternal distress. However, fetal distress and even demise can occur with seemingly minor maternal trauma. Signs of fetal distress include an abnormal baseline heart rate, decreased variability of heart rate, and fetal decelerations after contractions.

The normal fetal heart rate ranges from 120 to 160 beats/min; rates outside or trending toward these limits are ominous. Heart rate variability has two components. Beat-to-beat variability measures autonomic nervous function, whereas long-term variability indicates fetal activity. Heart rate variability increases with gestational age. The loss of beat-to-beat and long-term variability warns of fetal central nervous system depression and reduced fetal movement caused by fetal distress (Fig. 177.4).

Late decelerations are an indication of fetal hypoxia. These decelerations are relatively small in amplitude and occur after the peak or conclusion of a uterine contraction. By comparison, early decelerations are larger, occur with the contraction, and recover to baseline immediately after the contraction. Early decelerations may be vagally mediated when uterine contractions squeeze the fetal head, stretch the neck, or compress the umbilical cord. Variable decelerations are large, occur at any time, and are possibly caused by umbilical cord compression (Fig. 177.5).

Mother Stable, Fetus Stable

Minor trauma does not exempt the fetus from significant injury. It is estimated that up to 3% of all minor trauma results in fetal loss,

TABLE 177.3 Fetal Viability in Trauma

Weeks of Gestation	6-Month Survival (%)	Survival With No Severe Abnormalities (%)
22	0	0
23	15	2
24	56	21
25	79	69

Data from: Morris JA Jr, et al. Infant survival after cesarean section for trauma. *Ann Surg*. 1996;223:481.

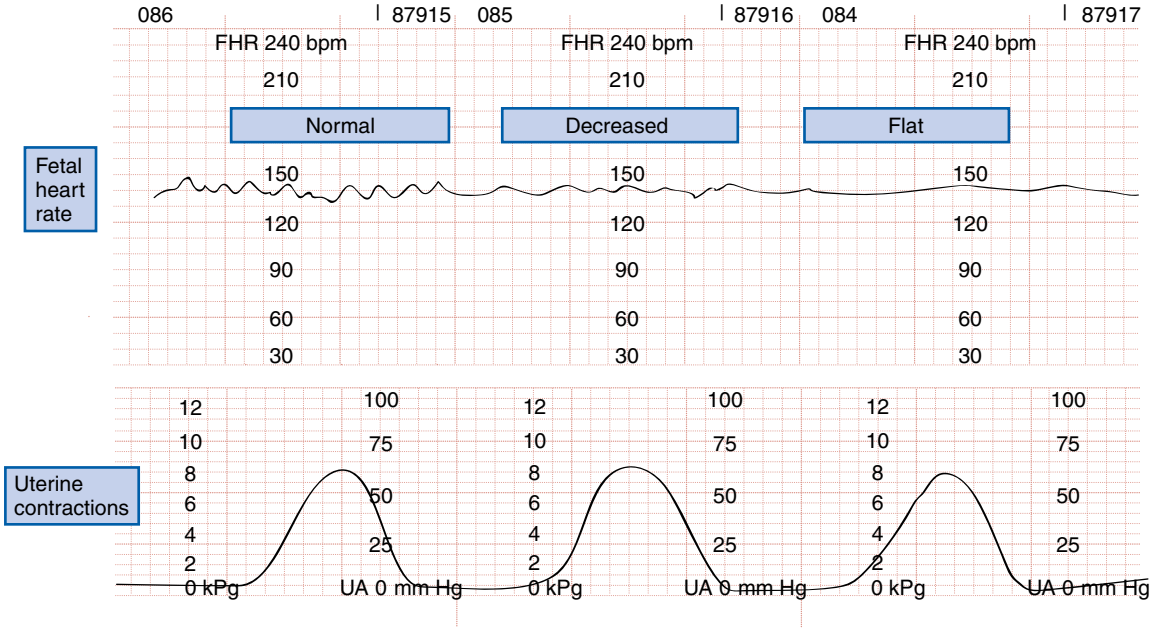

Fig. 177.4 Types of fetal heart rate variability. *bpm,* Beats per minute; *FHR,* fetal heart rate; *UA,* uterine activity.

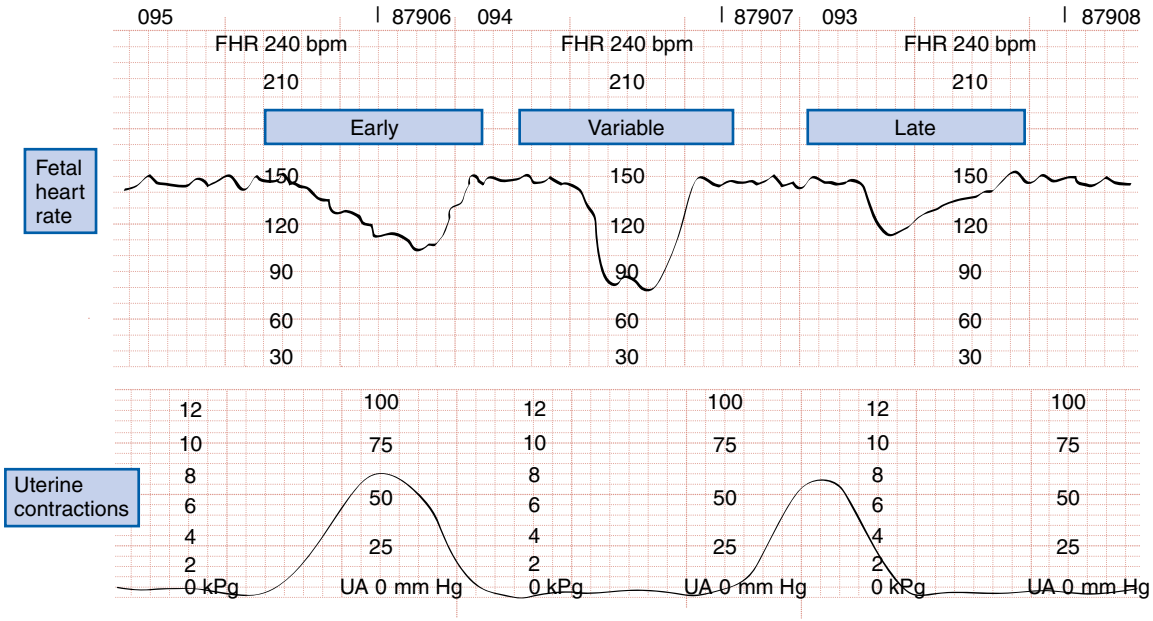

Fig. 177.5 Types of fetal heart rate decelerations. *bpm,* Beats per minute; *FHR,* fetal heart rate; *UA,* uterine activity.

typically from placental abruption. Therefore, once the traumatized mother is stabilized, the focus of care is directed toward the fetus. For the viable fetus (greater than 22 to 24 weeks' gestation), monitoring is the next step. Continuous monitoring maintained throughout all diagnostic and therapeutic actions is advisable. Because direct impact is not necessary for fetoplacental pathology to occur, the traumatized pregnant woman with no obvious abdominal injury still benefits from monitoring.

The recommended 4 hours of cardiotocographic observation of the viable fetus is extended to 24 hours if at any time during the first 4 hours there are more than three uterine contractions per hour, uterine tenderness persists, results on a fetal monitor strip are worrisome, vaginal bleeding occurs, the membranes rupture, or any serious maternal injury is present. Most cases of placental abruption after maternal trauma are detected within the first 4 hours of monitoring.

On discharge from the hospital, the pregnant woman should be instructed to record fetal movements during the next week. If fewer than four movements per monitored hour are noted, the patient should see her obstetrician immediately and a nonstress test is warranted. The occurrence of preterm labor, membrane rupture, vaginal bleeding, or uterine pain also necessitates prompt reevaluation. Serial ultrasound and fetal heart rate tests on viable fetuses a few days after maternal trauma and periodically throughout the remaining portion of the pregnancy are helpful in monitoring fetal well-being.

Mother Stable, Fetus Unstable

Fetal death rates after maternal trauma are three to nine times higher than maternal death rates. If a viable fetus remains in distress despite optimization of maternal physiology, cesarean section should be considered.

Although fetal viability is first reached at 22 to 24 weeks, the ultimate determinant of the age of fetal viability is the level of neonatal care provided by the intensive care nursery unit in each hospital or accessible regional facility. Determining gestational age for fetuses of less than 29 weeks may be difficult. Emergency decisions on fetal viability are therefore made on the basis of the best ultrasonography and gestational age information available.

The presence of fetal heart tones is an important survival marker for fetuses about to undergo emergency cesarean section. The fetal survival rate is zero if there are no fetal heart tones present when emergency cesarean section commences. If fetal heart tones are present and the gestational age is 26 weeks or more, the infant survival rate may be as high as 75%.

Besides fetal distress, other reasons for a cesarean section include uterine rupture, placental rupture with significant vaginal bleeding, fetal malpresentation during preterm labor, and situations in which the uterus mechanically limits maternal repair. Fetal demise without any of the aforementioned conditions is not an indication for cesarean section, because most will pass spontaneously within 1 week.

Mother Unstable, Fetus Unstable

If the mother's condition is critical, primary repair of her wounds is the best course. This may apply even when the fetus is in distress, because a critically ill mother may not be able to withstand an additional operative procedure such as cesarean section, which prolongs laparotomy time and likely substantially increases blood loss. The best initial action on behalf of the fetus is early and rapid restoration of normal maternal physiology. If it is felt that the unstable mother can tolerate an emergency cesarean section, it should be considered for the distressed, viable fetus.

As with nonpregnant patients, operative intervention for blunt trauma and above-the-uterus stab wounds is dictated by clinical findings and diagnostic test results. Above-the-uterus intraperitoneal gunshot wounds require exploration. In situations of severe maternal hemorrhage, massive transfusion protocols should be initiated with fresh frozen plasma, platelets, and red blood cells in a 1:1:1 ratio to lower the rate of coagulopathy and improve survival. There is little evidence to support a definitive management strategy for penetrating trauma to the gravid uterus. In situations of a hemodynamically stable mother, expectant management has been recommended. However, no prospective study has verified this. Damage to the uterus alone can be quite devastating because of its increased circulation. Without exploration, it is impossible to know the occurrence, size, or depth of uterine penetration, and there are no guidelines indicating whether a uterine wound can be left unsutured without incurring an increased risk of infection or delayed uterine rupture. We recommend laparotomy or laparoscopy as the safest means of managing penetrating uterine wounds because missed maternal injuries can quickly compromise the fragile fetus.

Defibrillation

Electrical flow that bypasses the fetus has little effect on the pregnancy. Maternal elective and emergent cardioversion have been performed safely for cardiac dysrhythmias in all three stages of pregnancy. Energies up to 300 Joules on a monophasic defibrillator have been used without affecting the fetus or inducing preterm labor. Although the amount of energy reaching the fetal heart is thought to be small, it is advisable to monitor the fetal heart during maternal cardioversion.

Resuscitative Hysterotomy

Restoration of maternal and thus fetal circulation is the optimal goal with maternal hemodynamic instability. During maternal resuscitation, adequate oxygenation, fluid loading, and a 30-degree left tilting position or manual displacement of the gravid uterus is recommended to improve maternal circulation. If there is no response to advanced cardiac life support, a resuscitative hysterotomy, formerly known as a perimortem cesarean section, should be initiated by 4 minutes and completed by 5 minutes after the onset of maternal cardiac arrest with no return of spontaneous circulation (ROSC).[14-19]

In the event of maternal cardiopulmonary arrest, resuscitative hysterotomy is recommended to rapidly deliver the fetus to relieve aortocaval compression, improve hemodynamics, and optimize maternal and fetal survival.[20] A resuscitative hysterotomy is a rare but potentially lifesaving procedure for both the mother and neonate and is recommended only if uterine size exceeds the umbilicus (20 weeks' gestation or greater). Time since maternal circulation ceased is the critical factor in fetal outcome. Delivery increases venous return and cardiac output by 25% to 30% and leads to higher rates of ROSC and survival benefit for mother. Beyond 20 minutes, there is virtually never survival or favorable neurologic outcome for either mother or fetus.

The most experienced physician available should perform the procedure as cardiopulmonary resuscitation (CPR) is continuing. A midline vertical incision is made from the epigastrium to the symphysis pubis. The uterus is then entered with a midline vertical incision. If necessary, the placenta is incised to reach the fetus; once the fetus has been delivered, the cord is clamped and cut. Maternal revival after delivery of the fetus is reported due to relief of vena caval compression and improved hemodynamics.

DISPOSITION

The emergency clinician should consider the stability of the mother and the viability of the growing fetus when making management and disposition decisions. Any pregnant woman at 22 to 24 or more weeks of gestation who has sustained blunt trauma should undergo at least 4 hours of fetal monitoring, even if she appears well. In general, pregnant women who sustain minor trauma have a favorable pregnancy outcome. Other admission and operative criteria are similar for pregnant and nonpregnant trauma patients.

The references for this chapter can be found online at ExpertConsult.com.

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CHAPTER 177: QUESTIONS AND ANSWERS

1. A 30-year-old female who is 28 weeks' gestation presents to the emergency department after being a restrained passenger in a low-speed MVC. Which of the following is the best indicator of fetal outcome in this scenario?

a. Abdominal tenderness
b. Cardiotocographic monitoring for 4 hours
c. Maternal blood count and arterial blood gas results
d. Maternal vital signs
e. Ultrasonography

Answer: B. For women with mild blunt trauma, fetal outcome is not predicted by maternal vital signs, abdominal tenderness, blood tests, or ultrasound results. Only cardiotocographic monitoring for a minimum of 4 hours is useful to predict fetal outcome. Fetal monitoring can identify fetal distress and the need for further intervention.

2. Which of the following factors is most concerning in the presentation of a pregnant trauma patient?

a. Diastasis of the symphysis pubis
b. Electrocardiogram (ECG) findings of Q waves in III and aV_F
c. Hematocrit 34% in third trimester
d. Hypotension in the third trimester
e. Respiratory alkalosis in the third trimester

Answer: D. Blood pressure declines in the first trimester, levels out in the second trimester, and then returns to nonpregnant levels during the third trimester. In pregnancy, minute ventilation increases, leading to hypocapnia. Therefore, a partial pressure of arterial carbon dioxide ($Paco_2$) of 35 to 40 mm Hg may indicate inadequate ventilation and impending respiratory decompensation. The physiologic anemia of pregnancy, resulting from a 48% to 58% increase in plasma volume and only an 18% increase in red blood cells, results in hematocrits of 32% to 34% by gestational age of 32 to 34 weeks. Electrocardiographic changes include a left-axis shift averaging 15 degrees, caused by diaphragm elevation. Consequently, flattened T waves or Q waves in leads III and aV_F may be seen.

3. A 26-week gravid woman presents to the emergency department (ED) after a moderate-speed motor vehicle collision (MVC). The patient is without complaints, and her vital signs are as follows: blood pressure, 100/60 mm Hg; heart rate, 100 beats per minute; and respiratory rate, 18 breaths per minute. Ultrasound examination shows good fetal movement, with a fetal heart rate of 150 beats per minute. What is the appropriate disposition for this patient?

a. Consult obstetrics for a minimum of 4 hours of cardiotocographic monitoring.
b. Perform a FAST examination and if negative discharge home.
c. Consult trauma and obstetrics for admission and serial examinations.
d. Consult trauma surgery for exploratory laparotomy.
e. Discharge the patient with close follow-up with obstetrics.

Answer: A. Placental abruption results when the inelastic placenta shears away from the elastic uterus during sudden deformation of the uterus. Because deceleration forces can be as damaging to the placenta as direct uterine trauma, abruption can occur with little or no external sign of injury to the abdominal wall. For the viable fetus (more than 22 to 24 weeks' gestation), monitoring is the next step.

CHAPTER 177: QUESTIONS AND ANSWERS—cont'd.

4. A 26-year-old, 30-week gestation woman presents unresponsive with cardiopulmonary resuscitation (CPR) in progress after a high-speed motor vehicle collision (MVC). The patient lost her vital signs 3 minutes before arrival in the emergency department (ED). What is the most appropriate next step in the management of this patient?

a. Transfer to the operating room for emergency cesarean section by obstetrics
b. Resuscitative hysterotomy with vertical midline incision
c. Thoracotomy with cardiac massage
d. Administer epinephrine and continue ACLS guidelines for cardiac arrest
e. Defibrillate immediately at 300 J

Answer: B. In the event of maternal cardiopulmonary arrest, resuscitative hysterotomy is indicated in any pregnancy of greater than 20 weeks' gestation (above the umbilicus) to improve both maternal and fetal survival. It should ideally be performed within 4 minutes of loss of spontaneous circulation and completed by 5 minutes of no ROSC. The most experienced physician available should perform the procedure.

5. A 28-week pregnant patient comes in after a gunshot wound to the epigastrium. Her blood pressure is 95/30 and her heart rate is 125 after receiving 1 liter IV fluids by EMS en route. What is the optimal management for this patient?

a. Explore the wound locally for entrance and exit wounds.
b. Expectant management with serial abdominal examinations.
c. Intraoperative exploratory laparotomy or laparoscopy by a trauma surgeon.
d. Fetal monitoring for a minimum of 4 hours

Answer: C. The gravid uterus affects the injury pattern seen with penetrating trauma to the upper abdomen with the probability of harm to the bowel, liver, or spleen at almost 100%. The gravid uterus tends to protect abdominal organs from trauma but substantially increases the likelihood of bowel injury from penetrating trauma to the upper abdomen. A trauma surgeon/trauma service should be activated or consulted. With persistent hypotension after an initial 1-liter IV fluid bolus, the massive transfusion protocol should be initiated in anticipation of the expected course of action. The patient will need to go to the operating room for an exploratory laparotomy.