Trauma in Pregnancy

Jeffrey Sakamoto, MD[a], Collin Michels, MD[a], Bryn Eisfelder, MD[a], Nikita Joshi, MD[b,*]

KEYWORDS

• Trauma in pregnancy • Blunt trauma • Penetrating trauma

KEY POINTS

- Trauma in pregnancy is challenging because there are two patients to consider during resuscitation. It may not be clear based on history or physical that a patient is pregnant, and the physician should assess for pregnancy in patients of child-bearing age.
- Prioritization of maternal resuscitation is important to ensure optimal outcome for mother and fetus, which includes proceeding with medications and radiology examinations because they are indicated without delay.
- Trauma management in pregnancy requires coordination between multiple specialties including emergency medicine, trauma surgery, obstetrics, and neonatology.
- Pregnant trauma patients often require prolonged observation in labor and delivery units after initial stabilization in the emergency department. This may require transfer to another facility for higher level of care.

INTRODUCTION

Although pregnant trauma patients present infrequently to the emergency department (ED), it is one of the most common contributors to maternal and fetal morbidity and mortality.[1–8] Up to 1.5% of women admitted for traumatic injuries are pregnant[4]; however, immediate recognition of pregnancy is not always possible, especially in cases of first-trimester pregnancy, morbid obesity, or in critically injured patients. Additional to the rarity of presentation and complicated pathophysiology, there is the cognitive load of resuscitating two patients, mother and fetus; working with multiple specialties including trauma, obstetrics, and neonatology; and processing emotional and social issues that can arise. Furthermore, the clinical course is difficult to predict because of a lack of correlation between the degree of trauma and clinical outcome.[2] Unique challenges in pregnant trauma patients are listed in **Box 1**.

Disclosure Statement: None of the authors have any relationship with a commercial company that has a direct financial interest in subject matter or materials discussed in article or with a company making a competing product. The authors acknowledge the contribution of Dr Kimberly S. Harney, Clinical Professor, Obstetrics, Stanford University, to this article.

[a] Department of Emergency Medicine, Stanford University, 900 Welch Road, Suite 350, Palo Alto, CA 94304, USA; [b] Alameda Health Systems, 490 Grand Avenue, Oakland, CA 94610, USA
* Corresponding author.
E-mail address: njoshi8@gmail.com

Emerg Med Clin N Am 37 (2019) 317–338
https://doi.org/10.1016/j.emc.2019.01.009 **emed.theclinics.com**

Box 1
Unique challenges in pregnant trauma patients

- Complex physiologic adaptations of the pregnant patient throughout pregnancy
- Need for multidisciplinary approach with multiple specialties
- Mitigation of exposure to radiation and other teratogens
- Management of pregnancy-specific related condition (ie, Rhesus factor isoimmunization, placental abruption)
- Management of two patients concurrently

BACKGROUND AND EPIDEMIOLOGY

Trauma has been found to be the leading nonobstetric cause of maternal death during pregnancy, and is associated with up to 20% of maternal deaths in the United States.[1,9] Traumatic injuries are estimated to complicate up to 1 in 12 pregnancies.[2–4] In 2017, a study involving 1148 pregnant trauma patients found that pregnant women had significantly higher mortality compared with nonpregnant women, with a relative risk (RR) of 1.6.[1]

Risk factors commonly associated with trauma in pregnancy include[1,2,4,9]:

- Age less than 26 years
- African-American or Hispanic ethnicity
- Medicaid insurance
- Lower socioeconomic status
- Minimal or no prenatal care in the first trimester

Risk stratification and identification of potential maternal and fetal complications are also difficult. Even minor injuries as evaluated by the Injury Severity Score,[10] a validated tool in predicting mortality in nonpregnant populations,[11,12] is not predictive of fetal morbidity and mortality, and can still be associated with adverse pregnancy outcomes.[2,8]

Mechanism of Injury

Unintentional or nonviolent trauma accounts for the largest portion of trauma in pregnancy, including motor vehicle accidents (MVAs) and falls.[8] Intentional or violent trauma accounts for approximately 16% of traumatic injuries in pregnant women, and includes suicide, gunshot wounds, stab wounds, sexual assault, strangulation, and domestic violent (DV). Blunt trauma including MVAs and falls accounts for 88% to 92% of injuries, penetrating trauma including gun shot wounds (GSWs) and stab wounds account for approximately 2% to 7%, and burn injuries up to 4%. Although most traumas are nonviolent in cause, pregnant patients are nearly twice as likely to experience violent trauma compared with nonpregnant patients with increased mortality and a RR of 3.14.[1,2,13–17]

ANATOMY AND PHYSIOLOGY OF PREGNANT PATIENTS

As seen in **Fig. 1**, the uterus remains within the pelvis until approximately 12 weeks gestational age (GA), reaching the umbilicus by 20 weeks GA, and the costal margins by 34 weeks GA.[18] By the end of the third trimester, the uterus size significantly alters anatomic location and function of abdominal and pelvic structures. **Tables 1** and **2** summarize pertinent anatomic and physiologic changes as it relates

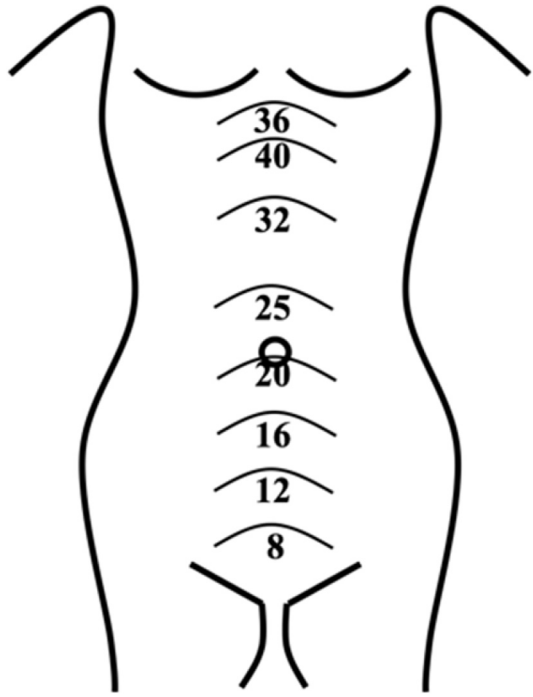

Fig. 1. Approximate location of uterine fundus at different gestational ages.

to trauma management.[18–24] Understanding the clinical impact of these changes is important because it affects symptoms and manifestations of traumatic injuries.

Cardiovascular Changes

Cardiovascular adaptations allow for optimal oxygen (O_2) delivery to maternal and fetal tissues. Plasma volume begins to expand by 6 to 8 weeks GA, increasing cardiac output up to 45%.[6,18,21,24] Blood pressure decreases throughout pregnancy with average diastolic blood pressure decrement of 10 to 15 mm Hg, and average systolic blood pressure decrement of 5 to 10 mm Hg.[19] After 20 weeks GA, the uterus rises to the level of the inferior vena cava (IVC), causing compression of the IVC in the supine position, decreasing cardiac preload and cardiac output by 10% to 30%.[20,21] The changes can cause difficulty in identification of maternal hemorrhagic shock with up to 30% to 35% of circulating blood volume (almost 2000 mL) lost before exhibiting hypotension. Increased blood flow to the uterus and injuries is a significant source of hemorrhage. There may also be marked venous congestion throughout the pelvis and lower extremities increasing the risk of retroperitoneal hemorrhage with pelvic injuries.[18,22,25]

Pulmonary Changes

Respiratory changes to optimize fetal oxygenation lead to 40% increase (approximately 200 mL) in tidal volume leading to increased minute ventilation[26] and lower arterial $Paco_2$ (mean value of 30 mm Hg in pregnancy). The diaphragm rises up to 4 cm during pregnancy, resulting in perceived penetrating chest trauma to actually be intra-abdominal.[27]

Table 1
Anatomic changes in pregnancy

Structure	Change	Clinical Significance
Airway	Edema and friability	Difficult intubation
Uterus	Extends beyond bony pelvis after first trimester	Direct uterine injury
	Gravid uterus >20 wk GA	Supine hypotension secondary to IVC compression
Bladder	Moves anteriorly and superiorly into abdomen in third trimester	Direct bladder injury
	Physiologic bladder and ureter compression	Incorrect identification of renal obstruction, when hydronephrosis and hydroureter can be physiologic in pregnancy
Diaphragm	Elevates superiorly 4 cm	Pneumothorax, tension pneumothorax requiring higher thoracostomy tube placement 2–3 interspaces superiorly
Small bowel	Higher displacement into abdomen	Direct small bowel injury with penetrating trauma to upper abdomen
Peritoneum	Abdominal wall stretches as pregnancy progresses	Underestimation of intra-abdominal bleeding or organ injury because of blunted response to peritoneal irritation
Ligaments of PS and SI joints	Loosening	Incorrect identification of pelvic disruption on radiograph because of baseline diastasis

Abbreviations: IVC, inferior vena cava; PS, pubic symphysis; SI, sacroiliac.

Renal Changes

By 26 weeks GA, the renal plasma blood flow and glomerular filtration rate increase resulting in decreased serum levels of creatinine and blood urea nitrogen.[26] Renal excretion of bicarbonate compensates for respiratory alkalosis resulting in decreased levels of serum sodium bicarbonate to 19 to 20 mEq/L.[26] The bladder may be displaced anteriorly and superiorly, causing susceptibility to injury.[22] Physiologic hydronephrosis and hydroureter may be seen on radiology imaging.[21,24]

Gastrointestinal Changes

Progesterone mediates delays in gastric emptying, decreased intestinal motility, and decreased lower esophageal sphincter tone, which increases the risk of aspiration.[22,23] Early gastric decompression should be considered in gravid women greater

Table 2
Physiologic changes in pregnancy

System	Physiologic Change	Clinical Significance
Airway		
Pulm	Airway edema	Difficulty airway, may require smaller ETT (6.0 and 6.5) and additional airway adjuncts
	↑ O_2 consumption, ↓ RV, and ↓ FRC	Requires preoxygenation with high flow O_2 before induction
GI	↓ Gastric emptying, ↓ LES tone	↑ Risk of aspiration
Breathing		
Pulm	↑ TV and ↑ MV	Compensated respiratory alkalosis, maintain $Etco_2$ 30–35 mm Hg
	Elevation of diaphragm	Place chest tubes 1–2 intercostal spaces above fifth interspace
Circulation		
CV	↑ Plasma volume	Delayed recognition of hemorrhagic shock with large-volume blood loss; physiologic anemia
	↑ HR and ↓ BP	Vital signs poor marker of hemodynamic stability
	↑ Uterine and bladder blood flow	↑ Risk of maternal hemorrhage with direct injury
	↑ Vascular congestion	↑ Risk of retroperitoneal hemorrhage or lower extremity brisk bleed
Miscellaneous		
Renal	↑ rPBF, ↑ GFR, and ↓ Serum Cr	Caution with drugs excreted through renal system
	↑ Bicarb excretion	↓ HCO_3 on ABG (19–20 mEq/L), increased susceptibility to acidosis
Heme	↑ Fibrinogen, ↑ D dimer, ↓ PT, PTT, ↓ PLTs	Propensity to develop DIC

Abbreviations: ABG, arterial blood gas; BP, blood pressure; Cr, creatinine; CV, cardiovascular; DIC, disseminated intravascular coagulation, ETT, endotracheal tube; FRC, functional residual capacity; GFR, glomerular filtration rate; GI, gastrointestinal; HR, heart rate; LES, lower esophageal sphincter; MV, minute ventilation; PT, prothrombin time; PLT, platelet; PTT, partial thromboplastin time; Pulm, pulmonary; rPBF, renal plasma blood flow; RV, residual volume; TV, tidal volume.

than 16 weeks GA with altered mental status, especially if undergoing intubation.[18] The most common cause of abdominal hemorrhage is secondary to splenic injury.[22]

Hematopoietic Changes

Beyond the increase in plasma volume, other hematopoietic changes that gradually occur are summarized in **Table 3**.[18,21,23,24] These alterations make it challenging to detect hemorrhage and shock.

ANATOMY AND PHYSIOLOGY OF FETUS

Fetal O_2 requirements lead to increased blood flow to the uterus at the end of the third trimester. Uterine blood flow is directly proportional to maternal mean arterial

Table 3
Summary of hematopoietic differences in pregnancy

Laboratory Studies (Units)	Nonpregnant Women Range	Pregnant Women	
		Change	Range
Hemoglobin (g/dL)	12–15.8	↓	9–11
Hematocrit (%)	36–47	↓	31–35
White blood cell count ($\times 10^3$/mm^3)	3.5–9.1	↑	14–16[a]
Platelets ($\times 10^9$/L)	250[b]	↓	213[b]
Fibrinogen (mg/dL)	256[b]	↑	473[b]
Factor VII (%)	99.3[b]	↑	181.4[b]
Factor X (%)	97.7[b]	↑	144.5[b]

[a] Peak of 25 during labor.
[b] Mean value.

pressure, and inversely proportional to the resistance of the uterine vasculature.[20,22] This makes uteroplacental perfusion sensitive to decrease in maternal blood pressure during resuscitation and maternal hemorrhage.[25] The placenta creates a large, inelastic, and vascular conduit through which mother and fetus can exsanguinate during placental abruption without obvious external signs. In the event of uterine laceration or rupture, rapid maternal exsanguination with significant impact to the fetus can occur.[24] Fetal hemoglobin and relative acidemia compared with mother causes slight preservation of fetal oxygenation regardless of maternal Pao_2 levels.[22] However, these factors are not fully protective during prolonged maternal hypoxia.[18,20,22]

MATERNAL TRAUMA RESUSCITATION

As with nonpregnant patients, the trauma evaluation of a pregnant patient starts with airway, breathing, and circulation. All women should be considered pregnant until proven otherwise, because it was found that 3% of women admitted to a trauma center were pregnant and of those, 11% were incidental findings.[28]

Primary Survey

Airway

Advanced airway intubation is an independent risk factor of trauma-related mortality in pregnant trauma patients, with an RR of 6.0.[1] Anatomic and physiologic changes make the pregnant airway more challenging with a greater risk of airway management problems than nonpregnant patients, with up to 1 in 250 failed intubations found in a surgical setting.[29] Pregnant women may have decreased ability to maintain a patent airway and sufficient ventilation, resulting in fetal distress. Maternal hyperventilation and alkalosis can reduce uterine blood flow via uterine vasoconstriction, also leading to fetal distress.[30] Airway edema, hyperemia, and landmark distortion can cause difficult visualization during laryngoscopy.[31]

It is reasonable to have a lower threshold for advanced airway management given the low maternal oxygen reserve and exaggerated fetal response to maternal hypoxia. Preoxygenation and apneic oxygenation is critical to prevent maternal and fetal hypoxia throughout the procedure.[32] Specific patient positioning beyond the sniffing position is essential to maintain preload from left uterine displacement either manually (**Fig. 2**) or with a wedge under the right hip to 30° to reduce aortocaval compression, if GA is 20 weeks.[33] Rapid sequence induction and anesthesia maintenance

Fig. 2. Manual left uterine displacement. (*Courtesy of* Christie Sun, MD, La Jolla, CA.)

medications, such as volatile agents, depolarizing and nondepolarizing neuromuscular blockers, fentanyl, and morphine, are safe to administer during pregnancy.[33] Cricoid pressure should be used to decrease the risk of aspiration of gastric contents. Blind nasotracheal intubation is not advised because of engorgement and friability of nasal mucosa from increased estrogen.

The ED provider should have the following equipment on hand for intubation:[20]

- Adjunctive airway equipment, such as laryngeal mask airway and videolaryngoscope
- Smaller size endotracheal tube (6.0–6.5) and stylets
- Gum elastic bougie
- Short laryngoscope handles

The initial ventilator settings should be similar to nonpregnant women with goals of P_{CO_2} of 28 to 35 mm Hg and should avoid respiratory alkalosis to prevent decrease in uteroplacental flow.[20] Early nasogastric tube placement is warranted because of the increased risk of gastroesophageal reflux.[23,33]

Breathing

The physiologic changes to the pulmonary system cause a significantly reduced oxygen reserve. This impairs compensation during respiratory compromise, and can result in rapid development of maternal hypoxia.[22] In trauma, supplemental O_2 is indicated with pregnant women, with pulse oximetry goal of greater than 95% to maintain Pa_{O_2} greater than 70 mm Hg.[20,27] Physiologic changes in pregnancy also cause a lower Pa_{CO_2}.[26] Therefore, Pa_{CO_2} of 35 to 40 mm Hg may indicate inadequate ventilation and impending respiratory decompensation in a pregnant woman. Additionally, the superior displacement of the diaphragm should be considered before needle decompression or tube or catheter thoracostomy.[24]

Circulation

Access with two large-bore intravenous (IV) lines should be placed to facilitate rapid crystalloid infusion, volume expansion, and blood transfusions.[27] Femoral and lower extremity access should be avoided because of vascular congestion in the pelvis and lower extremities secondary to IVC compression by the uterus.[22] Patients who show signs of hypovolemia, such as tachycardia, hypotension, or abnormal fetal heart tracings, should receive IV fluid resuscitation. If the patient is thought to be

hemorrhaging or in hemorrhagic shock, blood products should be administered instead of crystalloid. Active hemorrhage should be controlled with tourniquet, direct pressure, or pelvic binders. Massive transfusion protocol (MTP) with emergency release O-negative blood should be activated in shock.[27,34]

Proper positioning, as discussed previously, with left uterine displacement (see Fig. 2) is critical for maternal hypotension in patients greater than 20 weeks GA to improve maternal venous return and cardiac output.[35] Decompression is accomplished by either turning the patient into a left lateral position, placing a wedge under the right hip, or manual displacement (Fig. 3).[27]

Secondary Survey

The secondary survey follows the primary survey, and consists of history, physical examination, and ultrasound to identify maternal injuries. Concomitant evaluation of the fetal heart rate should be initiated. If the GA is greater than 23 weeks, external fetal monitoring (EFM) should be used to assess fetal heart tones (FHTs) and uterine contractions. If the GA is less than 23 weeks, or if EFM is unavailable, M-mode on bedside ultrasound is used to ensure viability and fetal heart rate (normal range is 120–160 beats per minute). Often abnormal fetal heart tracings or heart rates are the first signs of instability. For example, the first manifestation of maternal hypovolemic shock is often uteroplacental insufficiency causing decreased variability and possible late decelerations on FHT.[27,36] This finding may be missed if there is delay in obtaining FHT.

History

History should be obtained regarding mechanism and severity of injury. Additional questions include presence of vaginal bleeding, leakage of fluid, contractions, and fetal movement especially if the fetus is viable and GA greater than 23 weeks. Further

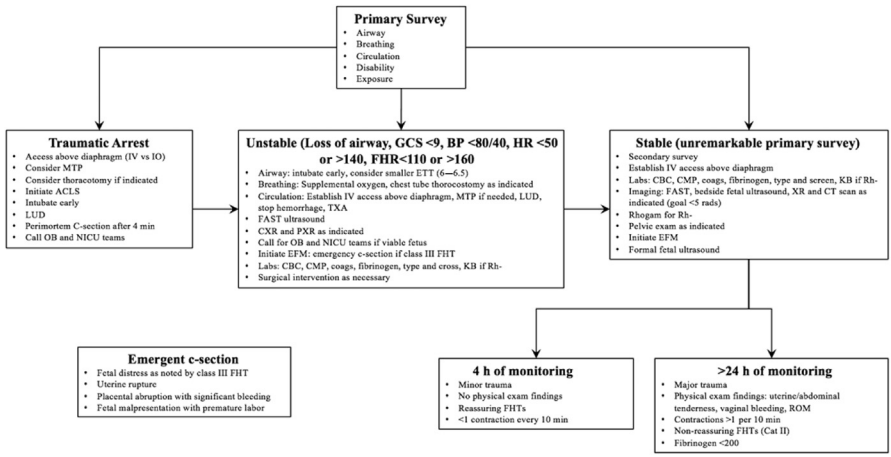

Fig. 3. Proposed algorithm for management of trauma in patients greater than 23 weeks GA. If less than 23 GA, consider focusing all resuscitation efforts on mother. ACLS, advanced cardiac life support; BP, blood pressure; CBC, complete blood count; CMP, complete metabolic panel; CT, computed tomography; CXR, chest radiograph; EFM, external fetal monitoring; ETT, endotracheal tube; FAST, focused assessment with sonography for trauma; FHR, fetal heart rate; FHT, fetal heart tole; GCS, glasgow coma score; HR, heart rate; IO, intra-osseous, KB, Kleihauer-Betke; LUD, lateral uterine displacement; NICU, neonatal intensive care unit; OB, obstetric; PXR, pelvic xray; Rh, rhesus factor; ROM, rupture of membranes; TXA, tranexamic acid; XR, xray.

obstetric history should be acquired including estimated delivery date, and complications affecting current pregnancy, such as diagnosis of preeclampsia, gestational diabetes, placenta previa, and oligohydramnios.

Physical examination

Physical examination of the pregnant trauma patient is similar to the nonpregnant patient and involves full exposure and thorough inspection and palpation of the entire body.[35] Key differences include physiologic vital sign alterations, abdominal examination, gravid uterus, pelvic examination, and fetal evaluation.[37] The abdominal examination can be unreliable in the pregnant patient because of gravid uterus and may mask peritonitis or an acute abdomen.[38] Abdominal contents are displaced superiorly, and penetrating injuries as high as the tip of the scapula posteriorly or the fourth intercostal space anteriorly may involve intra-abdominal organs. Bruising or ecchymosis of the abdomen or persistent pain on examination may indicate visceral injury.[27,39] Uterine tenderness is a sign of rupture or placental abruption.[40]

Pelvic examination

In the pregnant patient with GA greater than 23 weeks, it is important to evaluate for vaginal bleeding or leakage of fluid. The differential for vaginal bleeding includes placental previa, vasa previa, placental abruption, bloody show from cervical dilation with preterm labor, or uterine rupture. External physical examination may suffice if there is no vaginal bleeding, leakage of fluid, uterine tenderness, or contractions present. If there is concern, sterile speculum and digital examination should be performed to identify cause of bleeding, presence of tissue, cervical dilation and effacement, and fetal station. Ultrasound should be performed before examination to rule-out placenta previa. If there is concern for rupture of membranes, sterile speculum examination should be performed to assess for vaginal pooling of amniotic fluid or leakage of fluid from the cervical os.[41] Defer digital examination if high concern for preterm rupture of membranes to reduce infection risk. Ideally these examinations are performed in conjunction with obstetrics.

Bedside ultrasound

Bedside ultrasound is an important part of the secondary survey. Focused assessment with sonography for trauma (FAST) examination is pertinent in the hemodynamically unstable patient to exclude intra-abdominal hemorrhage. In three small studies, the sensitivity and specificity of FAST for detecting intra-abdominal hemorrhage were similar to nonpregnant patients at 80% to 85% and 98% to 100%, respectively.[42–44] One study had a lower sensitivity of 61%.[45] FAST should not be used to exclude intra-abdominal hemorrhage, but may save radiation and time in the setting of positive findings. If the patient is hemodynamically unstable and FAST positive, exploratory laparotomy should be performed. If the patient is stable with a positive FAST, computed tomography (CT) scan may still be necessary to determine whether intra-abdominal injury necessitates emergency surgery. Once the patient is stabilized, formal obstetric ultrasound is obtained.

Laboratory Tests

In general, indicated laboratory tests are similar to the nonpregnant patient. Physiologic changes in normal range for pregnant patients include leukocytosis, anemia, decreased creatinine, and increased clotting markers including fibrinogen and D dimer.[46] In addition to standard trauma laboratory studies, consider obtaining a type and screen, coagulation profile, fibrinogen, and Kleihauer-Betke (KB) test.

Type and screen

It is important to determine Rhesus factor (Rh) status because Rh-negative patients may develop alloimmunization if the fetus is Rh positive, which may lead to hemolytic disease of the fetus and newborn. This process can happen at 4 weeks in pregnancy.[47]

Kleihauer-Betke

Fetal-maternal hemorrhage can occur in up to 30% of pregnant patients.[48] The KB test uses a blood smear to quantify the amount of fetal hemoglobin in the maternal circulation. Because many fetal-maternal hemorrhage are subclinical, the American College of Obstetricians and Gynecologists (ACOG) guidelines advocate for KB testing in all pregnant trauma patients who are Rh negative because of concern for alloimmunization, which can happen at 4 weeks in pregnancy.[47] The KB test helps to correctly dose Rh immunoglobulin.[27,47,49,50]

Imaging Studies

Radiology plays an important role in trauma resuscitations, and it is no different in the pregnant trauma patient. Practitioners may grapple with this because of the perceived fetal risk of teratogenicity and carcinogenesis. In general, imaging should be performed as clinically indicated regardless of pregnancy status, including studies with ionizing radiation, especially in settings of maternal instability.

Per ACOG, Society of Obstetricians and Gynecologists of Canada, and Eastern Association of the Surgery of Trauma (EAST), radiation less than 5 rad (50 mGy) poses little to no risk of teratogenicity or fetal loss. Imaging is generally well below this threshold.[27,49,51,52] The fetus is at highest risk of teratogenicity at less than 12 weeks.[51] If necessary radiation exceeds 5 rad, discussing the risks and benefits of imaging studies and shared decision making with the patient should be done. Conflicting studies exist whether or not fetal exposure to ionized radiation is associated with carcinogenesis.[52–56]

Table 4 lists fetal radiation dose per imaging study. Strategies should be used to limit the amount of fetal radiation exposure when feasible, such as using lead protection over the gravid abdomen, selecting alternative protocols, and imaging with less radiation when it is feasible without compromising resuscitation.

Table 4
Fetal radiation doses of common trauma imaging

Imaging Study	Fetal Dose (mGy)
Head or neck CT	0.001–0.01
Radiography of any extremity	<0.001
Chest radiography (two views)	0.0005–0.01
Abdominal/pelvic radiography	0.1–3.0
Chest CT	0.01–0.66
Lumbar spine radiography	1.0–10
Abdominal CT	1.3–35
Pelvic CT	10–50

Abbreviation: CT, computed tomography.

Adapted from Committee on Obstetric Practice. Committee opinion no. 723: guidelines for diagnostic imaging during pregnancy and lactation. Obstet Gynecol 2017;130(4):e210–6.

Ultrasound

Ultrasound is generally safe and is easily repeated without harm if the clinical situation requires it. Although B-mode and M-mode are generally safe, there is a theoretic risk of increasing temperature with higher intensity ultrasound transduction through Doppler, use of which should be minimized or reserved only for obstetric ultrasounds.[51,57]

Radiographs

Radiographs of the chest, extremities, and spine generally expose the fetus to low levels of radiation and should be performed as indicated. Pelvic radiograph has a higher dose of radiation (up to 0.3 rad or 3 mGy). The treating physician may consider foregoing pelvic radiograph if abdominal and pelvic CT or MRI will be obtained.[51] Radiation exposure during image acquisition is reduced through such techniques as fluoroscopy, use of mini C-arm, strategic shielding of the fetus, and real-time dosimetry.[58,59]

Computed tomography

CT scans of the head, neck, and chest expose the fetus to low to moderate levels of radiation. CT of the abdomen and pelvis has a higher dose of radiation (up to 5 rad or 50 mGy) and but should be obtained if there is concern for intra-abdominal injury. Ultimately, given the potential risk of tetratogenesis and carcinogenesis, albeit low, radiation exposure should be limited to as low as reasonably possible, without compromising maternal resuscitation.[27,49,51] Iodinated contrast is generally safe in pregnancy and is considered a category B drug by the Food and Drug Administration (FDA).[51,60]

Magnetic resonance imaging

ACOG recommends no special considerations or restrictions for MRI in pregnant patients, whereas the 2010 EAST guidelines do not recommend MRI in the first trimester of pregnancy.[49,51] Gadolinium is no longer recommended in pregnant patients because there is increased risk in inflammatory skin conditions, stillbirth, and neonatal death.[51,61] In the setting of a stable patient with a low suspicion of injury, MRI may be a reasonable alternative to CT scan.[51,60] MRI may also be a superior method of imaging for follow-up studies to avoid additional radiation exposure. However, MRI should not be the initial diagnostic imaging choice if there is high suspicion for injury or instability.[60]

Treatment of Shock

Critical interventions, such as intubation, chest tube thoracostomy, venous access, and IV fluid administration, should all be performed as indicated with appropriate modifications for the pregnant patient. Shock, usually from life-threatening hemorrhage, is critically important to recognize and treat. The end goal should be balanced resuscitation, because overresuscitation with fluids can lead to pulmonary edema and worsened hemorrhage.[62,63] However, permissive hypotension as advocated by current trauma guidelines may be detrimental to fetal well-being, therefore resuscitation strategies should include real-time fetal heart tracing in reassessments and determining next steps in resuscitation.[27] Abnormal FHT can be the first sign of significant maternal hemorrhage.

Hemorrhage control

Controlling hemorrhage is an important part of managing shock. Tourniquets should be placed for exsanguinating extremities, pelvic binders for open book pelvic

fractures, and pressure should be placed on bleeding lacerations. If there are signs of intra-abdominal fluid on FAST in the setting of shock, emergent surgical intervention may be necessary.[49]

Massive transfusion protocol

Blood and blood products should be administered to all pregnant patients with hemorrhage and hemodynamic instability or signs of fetal distress. O-negative blood should be used as emergency release if cross-matched blood is not available.[27] MTP should be activated if necessary as per trauma guidelines in a 1:1:1 ratio of packed red blood cells to fresh frozen plasma (FFP) to platelets.[64] Most guidelines on obstetric hemorrhage are based on postpartum hemorrhage and also recommend similar 1:1:1 MTPs.[65–67]

Coagulopathy

FFP, platelets, and cryoprecipitate and fibrinogen are administered if there are signs of coagulopathy. If elevated international normalized ratio is persistent, it may be reasonable to give additional FFP (2–4 units) with a goal international normalized ratio less than 1.5.[67] FFP has an FDA category C rating. Prothrombin complex concentrate is also used to reverse coagulopathy.[68] Platelets may be transfused for goal platelet count greater than 50×10^9/L.[63,68] If fibrinogen is less than 2 g/L in the setting of life-threatening hemorrhage, fibrinogen (1–2 g) or cryoprecipitate (10 units) may be given.[63,66,68] No data exist on the safety of prothrombin complex concentrate, fibrinogen, or cryoprecipitate in pregnancy, but these products should be administered if life-threatening hemorrhage is present with evidence of coagulopathy.

Tranexamic acid

There are no studies evaluating tranexamic acid in the pregnant trauma patient, but it has been shown to reduce mortality in nonpregnant trauma and postpartum hemorrhage patients without increased incidence of venous thromboembolic events.[69,70] Therefore, it is reasonable to give tranexamic acid in the pregnant trauma patient with significant hemorrhage. Tranexamic acid is a category B medication per the FDA.

Vasopressors

In general, traumatic patients are hypotensive because of hypovolemia and hemorrhage and should be treated with volume rather than vasopressors initially. Vasopressors may also cause uteroplacental insufficiency because of effect on uterine tone and vasculature.[27] During cardiac arrest vasopressors should be used per advanced cardiac life support (ACLS) guidelines.[62,71] In specific situations, such as peri-intubation hypotension, it may be reasonable to use phenylephrine for vasoconstriction because this has been shown to be safe in pregnant patients experiencing hypotension from spinal epidural anesthesia.[72]

Other Interventions

Tocolytics/β-methasone

If the fetus is viable with GA greater than 23 weeks but less than 34 weeks, and the patient is in early preterm labor with cervical change, consider using tocolytics. Contraindications to tocolysis in the trauma patient include nonreassuring FHT and hemodynamically instability. Options include betamimetics (terbutaline), magnesium sulfate, or calcium antagonist (nifedipine).[73] If GA is greater than 24 weeks but less than 37 weeks, also consider the use of β-methasone to help with fetal lung maturity.[74,75]

Rhogam

Prophylactic Rho(D) immunoglobulin (Rhogam) should be given to all Rh-negative pregnant trauma patients within 72 hours.[27,47,49] One dose (300 mg) covers 30 mL of fetal blood.[27,47,76] If KB test estimates fetal blood within maternal to be greater than 30 mL, additional Rhogam doses should be given.[27]

Traumatic Arrest

In the event of traumatic arrest, ACLS should be initiated with primary focus on securing the airway, administering adequate oxygenation and ventilation, obtaining sufficient IV access with large-bore catheters above the diaphragm, and providing circulation with chest compressions and left uterine displacement, as well as balanced resuscitation with blood products.[62] If available, trauma, obstetric, anesthesia, and neonatal teams should arrive immediately to the bedside to aid in resuscitation.[77] Equipment for perimortem cesarean delivery (PMCD), thoracotomy, and other resuscitative interventions should immediately be brought to the bedside as indicated.

The focus of resuscitation should be on identifying and treating the underlying cause of traumatic arrest, such as hypovolemia or hemorrhage; tension pneumothorax; cardiac tamponade; hypoxia; or medical etiologies that may have occurred, such as seizure. Indications for thoracotomy should remain similar to the nonpregnant patient given the paucity of data in the pregnant patient.[62,78] Defibrillation, epinephrine, and other ACLS drugs should be administered without altering the dose, timing, or joules.[71,77,79]

Perimortem cesarean delivery

If maternal resuscitation is unsuccessful, the American Heart Association, ACOG, and EAST guidelines recommend emergency PMCD.[27,49,77,79,80] Indications for this procedure include[79,81–84]:

- Unsuccessful maternal resuscitation after 4 minutes
- GA at or greater than 23 weeks or fundal height above umbilicus

A case series by Katz and colleagues[81] identified 38 PMCDs in the setting of maternal cardiac arrest, eight involving trauma. Thirty of the 38 procedures resulted in the delivery of a viable infant, with 7 out of 38 involving fetus delivery greater than 15 minutes from maternal cardiac arrest. Twelve out of 20 cardiac arrests achieved return of spontaneous circulation after PMCD, although none involved traumatic arrest.[81]

FETAL EVALUATION AND RESUSCITATION

It is important to evaluate fetal well-being in parallel with maternal resuscitation, but not at the expense of maternal resuscitation. Strategies to evaluate the fetus include ultrasound, FHT, tocometry, and early involvement of obstetrics. If the fetus is previable, interventions are limited and resuscitation should focus on the mother.[27] In cases of viability, it is important to quickly assess FHTs for signs of distress. Emergency delivery or intervention is indicated in the setting of such injuries as placental abruption, uterine rupture, and maternal hemorrhage.[27] Fetal mortality in the setting of trauma is 61% in major trauma, and between 1.3% and 19% in all trauma based on other cohort studies.[39,85–87]

Ultrasound

Early involvement of obstetrics can allow for ultrasound evaluation beyond beside ultrasound to examine the fetus, placenta, amniotic fluid, and fetal position.[27] Signs of

placental abruption may be identified through ultrasound in the hands of an experienced user, although ultrasound is not sensitive for this diagnosis.[6,42,88,89]

Fetal Heart Monitoring and Tocometry

It is important to obtain FHTs and tocometry early and continuously in pregnant trauma patients. All pregnant trauma patients with GA 20 weeks should have minimum of 6 hours EFM observation, and longer if clinically warranted.[49] This provides surrogate information for fetal well-being, fetal acid-base status, and fetal perfusion.[90] Maternal hemorrhage, fetal hemorrhage, fetal hypoxia, placental abruption, and uterine rupture should be considered if FHTs shows signs of fetal distress.[27,87] In the setting of extreme fetal distress, urgent or emergent cesarean should be considered in consultation with neonatology and obstetrics.[27,36] Interventions for nonreassuring FHTs include continuing maternal resuscitation, supplemental oxygen, and left lateral decubitus positioning.[27] Tocometry is the external monitoring of maternal uterine contractions and should take place concurrently with fetal heart monitoring with GA greater than 23 weeks. In the case of contractions causing intense pain and regular contractions less than 10 minutes apart, consider placental abruption or preterm labor.[6,27]

Duration of External Fetal Monitoring

The duration of fetal monitoring is a topic of controversy. Studies have failed to observe reliable predictable factors for fetal demise, preterm delivery, or adverse outcome.[6,91] EAST guidelines suggest a minimum of 6 hours, ACOG guidelines do not give specific time but suggest a minimum of 6 hours.[49,80] Society of Obstetricians and Gynecologists of Canada recommends 4 hours if normal FHT and physical examination, but prolonged monitoring (24 hours) if there are any of the following present: uterine or abdominal tenderness, vaginal bleeding, contraction frequency of more than once per 10 minutes, rupture of membranes, nonreassuring FHTs, serum fibrinogen less than 200 g/L, and high-risk mechanism.[27]

Indications for Emergency Cesarean Section

Indications for emergency cesarean section in the operating room are determined with the consulting obstetrician. Obstetrics should immediately be consulted if there are signs of maternal instability, uteroplacental compromise, and decreased fetal well-being.[27,36] During traumatic cardiac arrest, PMCD should be initiated at 4 minutes and performed at the bedside without delay.

OBSTETRIC PATHOLOGY

Placental Abruption

Placental abruption is the leading cause of fetal death following blunt trauma.[49] A study involving 372 pregnant trauma patients (84% blunt, 16% penetrating) in the third trimester showed placental abruption as the most common complication at 3.5% with 54% mortality. Other studies have indicated a placental abruption rate between 5% and 50%.[89] The time course of presentation is usually delayed between 2 and 6 hours from initial trauma, up to 24 hours. Concerning symptoms include nonreassuring FHTs, vaginal bleeding, uterine tenderness, and contractions. Severe placental abruption can result in hemorrhagic shock and signs of disseminated intravascular coagulation.[49] Although the diagnosis is primarily clinical, CT scan and ultrasound may aid in decision making.[6,27,42,88,89,92–94] Immediate obstetric consultation should take place if there are any signs of placental abruption.

Uterine Injury

Uterine injuries in trauma include uterine contractions, serosal hemorrhage, abrasions, and complete uterine rupture.[27] Uterine contractions are the most common complication associated with maternal trauma.[18] Uterine rupture is rare with an incidence of approximately 0.7% and should be suspected in the setting of direct abdominal injury.[27,58,95]

Signs or symptoms of severe uterine injury and uterine rupture include peritoneal abdominal examination, maternal hemodynamic instability, irregular uterine contractions, palpable fetal parts, and sudden abnormal fetal heart rate pattern.[27] A FAST ultrasound examination will likely show free fluid in the abdomen in uterine rupture.[58] Unfortunately, fetal mortality with traumatic uterine rupture is almost universal. Early recognition is key with obstetric consultation for laparotomy to control hemorrhage, repair the uterus, and evaluate for fetal viability.[27]

Preterm Labor

Evaluation for preterm labor should be done in every injured pregnant patient. There is an associated higher risk of preterm delivery after trauma (RR, 2), increasing with injury severity and earlier GA.[96] Placental abruption may result in preterm labor in up to 20% of cases.[97] EFM should be used to monitor for any contractions, frequency, and regularity of contractions. If preterm labor is suspected and the patient is stable, transfer should be initiated to obstetric services is appropriate for further evaluation.

SPECIFIC MATERNAL INJURIES

Motor Vehicle Accidents

The overall incidence of MVAs during pregnancy has been estimated at 207 cases per 100,000 live births, and is the most common cause of traumatic injury.[85] The presence of illicit drugs or alcohol is significant with pregnancy-related traumas (19.6% and 12.9%, respectively), and is found present in up to 45% of pregnant women involved in MVAs.[4] Pregnant women involved in MVAs are also unrestrained up to 79% of the time. Not wearing a seatbelt is associated with more severe injuries, higher frequency of surgical interventions, and adverse fetal outcome.[98] Seatbelt placement also is an issue with nearly 50% of fetal losses associated with improper strap placement.[99] Seatbelts should be worn below the abdomen, touching the against thighs.[99] Airbag deployment has not been found to significantly increase likelihood of placental abruption or fetal loss.[13]

Up to 89% of pregnant women who are involved in MVAs can present with maternal or fetal complications requiring medical care, with most admissions occurring at greater than 20 weeks GA.[100] Among severely injured women in MVAs, placental abruption can occur in up to 40% of cases with maternal mortality rate of 13.7%.[13,86] However, even nonseverely injured pregnant women have an increased risk of preterm labor, placental abruption, and cesarean delivery.[7] Even minor accidents can create enough force to distort the uterine wall causing the placenta to shear leading to abruption.[6] The fetal mortality rate secondary to MVAs overall has been found to be 10.7%,[13] with an estimated 1300 to 3900 fetal losses per year in the United States secondary to MVAs.[101]

Falls

Falls are the second most common cause of blunt trauma in pregnant women, with an incidence of 48.9 cases per 100,000 live births.[102] Approximately one in four pregnant women fall at least once in pregnancy.[15] Falls are most common in the second and third trimesters,[102] likely caused by anatomic changes occurring in pregnancy leading

to a predisposition to falls.[103] Most falls occur from standing height and indoors, with 39% involving stairs.[15,102] Adverse events associated with falling include increase in rates of preterm labor (RR, 4.4), placental abruption (RR, 8), fetal distress (RR, 2.1), fetal hypoxia (RR, 2.9), and stillbirth (RR, 2).[102]

Penetrating Injuries

Penetrating trauma including GSWs in pregnancy is uncommon and incidence is estimated at 3.3 cases per 100,000 live births.[14,16,17,104] Maternal mortality is not significantly different in penetrating trauma mechanisms as compared with blunt; however, there are significant increases in maternal morbidity (66% vs 10%, respectively).[14] Common maternal complications include uterine injury and ileus.[14] Direct fetal injury and mortality in the third trimester is more common with penetrating trauma especially GSWs (up to 70%).[13,34,105]

Domestic Violence

DV or intimate partner violence is the most common form of intentional trauma, with up to 20.1% of women reporting physical or sexual abuse while pregnant.[106,107] The incidence of DV is estimated to be at 8307 cases per 100,000 live births.[108] Most often the domestic partner is identified as the aggressor in DV cases.[107] Risk factors for DV include substance abuse (maternal or partner), unintended pregnancy, history of DV before pregnancy, and unmarried status.[109,110] Adverse outcomes associated with DV include increased risk for spontaneous abortion and preterm birth (1.7), and increased risk for low birth weight, fetal distress, and fetal death (RR, 2).[109] The risk of fetal death has been found to be directly and significantly correlated to severity of maternal injuries.[111] At times, victims may present with a plausible story of injury and therefore DV may be overlooked, making it imperative to screen all pregnant trauma patients.

Burns

Burn injuries in pregnancy are rare, estimated at 0.17 cases per 100,000 live births.[112] Multiple studies have shown the overall maternal and fetal mortality to be high (up to 66%) regardless of total body surface area involved or GA.[113,114] Maternal and fetal mortality rates approach 100% if total body surface area exceeds 55%.[112,113,115] Therefore, urgent obstetric consultation for cesarean delivery is recommended in cases with total body surface area burn greater than 55%.[115] Burns during the first trimester have also been associated with spontaneous abortions,[116] which typically occur within 10 days after the burn.[117] Inhalation injury may also occur with burns making an already difficult airway even more challenging.[58] Co-oximetry and cyanide toxicity should also be considered because carbon monoxide and cyanide can transfer to the fetus.[58,115,116] Treatment is similar to nonpregnant patients with oxygen and hydrocobalamine.[58,112,115]

DISPOSITION

After stabilization, disposition from the ED is generally to labor and delivery for extended monitoring. If labor and delivery is not present at the hospital of the treating ED, transfer for higher level of care is warranted especially if there are signs of fetal distress or abnormalities on maternal physical examination.

Stable patients may be discharged following an appropriate period of observation. This includes at least 4 to 6 hours of observation for low-risk patients with normal physical examination and reassuring FHT, and at least 24 hours for high-risk patients

with abnormal physical examination, frequent contractions, or any signs of nonreassuring FHT. Patient should have close obstetric follow-up and strict return precautions including decreased fetal movement, vaginal bleeding, contractions, rupture of membranes, and severe pain.[27]

SUMMARY

The resuscitation and management of pregnant trauma patients is difficult because the provider must consider maternal physiologic changes during pregnancy; fetal well-being; and unique pathologies, such as placental abruption and preterm labor. Prioritization of maternal resuscitation is critical to ensure optimal outcome for the mother and fetus. Trauma in pregnancy, a rare event, also requires close communication and teamwork with multiple specialties.

REFERENCES

1. Deshpande NA, Kucirka LM, Smith RN, et al. Pregnant trauma victims experience nearly 2-fold higher mortality compared to their nonpregnant counterparts. Am J Obstet Gynecol 2017;217(5):590.e1-9.
2. El-Kady D, Gilbert WM, Anderson J, et al. Trauma during pregnancy: an analysis of maternal and fetal outcomes in a large population. Am J Obstet Gynecol 2004;190(6):1661–8.
3. Hill CC, Pickinpaugh J. Trauma and surgical emergencies in the obstetric patient. Surg Clin North Am 2008;88(2):421–40, viii.
4. Ikossi DG, Lazar AA, Morabito D, et al. Profile of mothers at risk: an analysis of injury and pregnancy loss in 1,195 trauma patients. J Am Coll Surg 2005;200(1):49–56.
5. Pak LL, Reece EA, Chan L. Is adverse pregnancy outcome predictable after blunt abdominal trauma? Am J Obstet Gynecol 1998;179(5):1140–4.
6. Pearlman MD, Tintinallli JE, Lorenz RP. A prospective controlled study of outcome after trauma during pregnancy. Am J Obstet Gynecol 1990;162(6):1502–7 [discussion: 1507–10].
7. Schiff MA, Holt VL. Pregnancy outcomes following hospitalization for motor vehicle crashes in Washington State from 1989 to 2001. Am J Epidemiol 2005;161(6):503–10.
8. Schiff MA, Holt VL, Daling JR. Maternal and infant outcomes after injury during pregnancy in Washington State from 1989 to 1997. J Trauma 2002;53(5):939–45.
9. Mattox KL, Goetzl L. Trauma in pregnancy. Crit Care Med 2005;33(10 Suppl):S385–9.
10. Senkowski CK, McKenney MG. Trauma scoring systems: a review. J Am Coll Surg 1999;189(5):491–503.
11. Copes WS, Champion HR, Sacco WJ, et al. The injury severity score revisited. J Trauma 1988;28(1):69–77.
12. El Kady D, Gilbert WM, Xing G, et al. Association of maternal fractures with adverse perinatal outcomes. Am J Obstet Gynecol 2006;195(3):711–6.
13. Petrone P, Jimenez-Morillas P, Axelrad A, et al. Traumatic injuries to the pregnant patient: a critical literature review. Eur J Trauma Emerg Surg 2017. [Epub ahead of print].
14. Petrone P, Talving P, Browder T, et al. Abdominal injuries in pregnancy: a 155-month study at two level 1 trauma centers. Injury 2011;42(1):47–9.
15. Dunning K, LeMasters G, Bhattacharya A. A major public health issue: the high incidence of falls during pregnancy. Matern Child Health J 2010;14(5):720–5.

16. Wall SL, Figueiredo F, Laing GL, et al. The spectrum and outcome of pregnant trauma patients in a metropolitan trauma service in South Africa. Injury 2014; 45(8):1220–3.
17. Zangene M, Ebrahimi B, Najafi F. Trauma in pregnancy and its consequences in Kermanshah, Iran from 2007 to 2010. Glob J Health Sci 2014;7(2):304–9.
18. Walls RM, Hockberger RS, Gausche-Hill M. Rosen's emergency medicine: concepts and clinical practice. 9th edition. Philadelphia: Elsevier; 2018.
19. Bardsley CEH. Chapter 103. Normal pregnancy. In: Tintinalli JE, Stapczynski JS, Ma OJ, et al, editors. Tintinalli's emergency medicine: a comprehensive study guide, 7e. New York: The McGraw-Hill Companies; 2011.
20. Burns B. Resuscitation in pregnancy. In: Tintinalli JE, Stapczynski JS, Ma OJ, et al, editors. Tintinalli's emergency medicine: a comprehensive study guide, 8e. New York: McGraw-Hill Education; 2016.
21. Cunningham FG, Leveno KJ, Bloom SL, et al. Maternal physiology. In: Williams obstetrics, 24e. New York: McGraw-Hill Education; 2013.
22. Delorio NM. Trauma in pregnancy. In: Tintinalli JE, editor. Tintinalli's emergency medicine: a comprehensive study guide, 8e. New York: McGraw-Hill Education; 2016.
23. Brown S, Mozurkewich E. Trauma during pregnancy. Obstet Gynecol Clin North Am 2013;40(1):47–57.
24. Petrone P, Marini CP. Trauma in pregnant patients. Curr Probl Surg 2015;52(8): 330–51.
25. Hill CC, Pickinpaugh J. Physiologic changes in pregnancy. Surg Clin North Am 2008;88(2):391–401, vii.
26. Yeomans ER, Gilstrap LC 3rd. Physiologic changes in pregnancy and their impact on critical care. Crit Care Med 2005;33(10 Suppl):S256–8.
27. Jain V, Chari R, Maslovitz S, et al. Guidelines for the management of a pregnant trauma patient. J Obstet Gynaecol Can 2015;37(6):553–71.
28. Bochicchio GV, Napolitano LM, Haan J, et al. Incidental pregnancy in trauma patients. J Am Coll Surg 2001;192(5):566–9.
29. Barnardo PD, Jenkins JG. Failed tracheal intubation in obstetrics: a 6-year review in a UK region. Anaesthesia 2000;55(7):690–4.
30. Meroz Y, Elchalal U, Ginosar Y. Initial trauma management in advanced pregnancy. Anesthesiol Clin 2007;25(1):117–29, x.
31. McKeen DM, George RB, O'Connell CM, et al. Difficult and failed intubation: incident rates and maternal, obstetrical, and anesthetic predictors. Can J Anaesth 2011;58(6):514–24.
32. Weingart SD, Levitan RM. Preoxygenation and prevention of desaturation during emergency airway management. Ann Emerg Med 2012;59(3):165–75.e1.
33. Moaveni DM, Varon AJ. Anesthetic management of the pregnant trauma patient. In: Varon AJ, Smith CE, editors. Essentials of trauma anesthesia. 2nd edition. Cambridge (United Kingdom): Cambridge University Press; 2017. p. 304–16.
34. Shah KH, Simons RK, Holbrook T, et al. Trauma in pregnancy: maternal and fetal outcomes. J Trauma 1998;45(1):83–6.
35. ATLS Subcommittee, American College of Surgeons' Committee on Trauma, International ATLS working group. Advanced trauma life support (ATLS(R)): the ninth edition. J Trauma Acute Care Surg 2013;74(5):1363–6.
36. Morris JA Jr, Rosenbower TJ, Jurkovich GJ, et al. Infant survival after cesarean section for trauma. Ann Surg 1996;223(5):481–8 [discussion: 488–91].
37. Smith KA, Bryce S. Trauma in the pregnant patient: an evidence-based approach to management. Emerg Med Pract 2013;15(4):1–18 [quiz: 18–9].

38. Cappell MS, Friedel D. Abdominal pain during pregnancy. Gastroenterol Clin North Am 2003;32(1):1–58.
39. Rothenberger D, Quattlebaum FW, Perry JF Jr, et al. Blunt maternal trauma: a review of 103 cases. J Trauma 1978;18(3):173–9.
40. Neilson JP. Interventions for treating placental abruption. Cochrane Database Syst Rev 2003;(1):CD003247.
41. Lee SE, Park JS, Norwitz ER, et al. Measurement of placental alpha-microglobulin-1 in cervicovaginal discharge to diagnose rupture of membranes. Obstet Gynecol 2007;109(3):634–40.
42. Goodwin H, Holmes JF, Wisner DH. Abdominal ultrasound examination in pregnant blunt trauma patients. J Trauma 2001;50(4):689–93 [discussion: 694].
43. Brown MA, Sirlin CB, Farahmand N, et al. Screening sonography in pregnant patients with blunt abdominal trauma. J Ultrasound Med 2005;24(2):175–81 [quiz: 183–4].
44. Meisinger QC, Brown MA, Dehqanzada ZA, et al. A 10-year retrospective evaluation of ultrasound in pregnant abdominal trauma patients. Emerg Radiol 2016;23(2):105–9.
45. Richards JR, Ormsby EL, Romo MV, et al. Blunt abdominal injury in the pregnant patient: detection with US. Radiology 2004;233(2):463–70.
46. Hellgren M, Blomback M. Studies on blood coagulation and fibrinolysis in pregnancy, during delivery and in the puerperium. I. Normal condition. Gynecol Obstet Invest 1981;12(3):141–54.
47. Practice bulletin no. 181 summary: prevention of Rh D alloimmunization. Obstet Gynecol 2017;130(2):481–3.
48. Rose PG, Strohm PL, Zuspan FP. Fetomaternal hemorrhage following trauma. Am J Obstet Gynecol 1985;153(8):844–7.
49. Barraco RD, Chiu WC, Clancy TV, et al. Practice management guidelines for the diagnosis and management of injury in the pregnant patient: the EAST practice management guidelines work group. J Trauma 2010;69(1):211–4.
50. Cunningham FG, Leveno KJ, Bloom SL, et al. Williams obstetrics. 24th edition. New York: McGraw-Hill Education; 2014. Available at: https://getitatduke.library.duke.edu/?sid=sersol&SS_jc=TC0001481193&title=Williams%20obstetrics%20study%20guide.
51. Committee on Obstetric Practice. Committee opinion no. 723: guidelines for diagnostic imaging during pregnancy and lactation. Obstet Gynecol 2017;130(4):e210–6.
52. Gjelsteen AC, Ching BH, Meyermann MW, et al. CT, MRI, PET, PET/CT, and ultrasound in the evaluation of obstetric and gynecologic patients. Surg Clin North Am 2008;88(2):361–90, vii.
53. Donnelly EH, Smith JM, Farfan EB, et al. Prenatal radiation exposure: background material for counseling pregnant patients following exposure to radiation. Disaster Med Public Health Prep 2011;5(1):62–8.
54. Ray JG, Schull MJ, Urquia ML, et al. Major radiodiagnostic imaging in pregnancy and the risk of childhood malignancy: a population-based cohort study in Ontario. PLoS Med 2010;7(9):e1000337.
55. Lowe SA. Diagnostic radiography in pregnancy: risks and reality. Aust N Z J Obstet Gynaecol 2004;44(3):191–6.
56. Doll R, Wakeford R. Risk of childhood cancer from fetal irradiation. Br J Radiol 1997;70:130–9.
57. American College of Obstetricians and Gynecologists. ACOG Practice Bulletin No. 101: ultrasonography in pregnancy. Obstet Gynecol 2009;113(2 Pt 1):451–61.

58. Huls CK, Detlefs C. Trauma in pregnancy. Semin Perinatol 2018;42(1):13–20.
59. Tejwani NKK, Looze C, Klifto CS. Treatment of pregnant patients with orthopaedic trauma. J Am Acad Orthop Surg 2017;25:e90–101.
60. Raptis CA, Mellnick VM, Raptis DA, et al. Imaging of trauma in the pregnant patient. Radiographics 2014;34(3):748–63.
61. Ray JG, Vermeulen MJ, Bharatha A, et al. Association between MRI exposure during pregnancy and fetal and childhood outcomes. JAMA 2016;316(9):952–61.
62. Part 10.7: cardiac arrest associated with trauma. Circulation 2005; 112(24_suppl). IV-146–IV-149. Available at: https://www.ahajournals.org/doi/pdf/10.1161/CIRCULATIONAHA.105.166569.
63. Cantle PM, Cotton BA. Balanced resuscitation in trauma management. Surg Clin North Am 2017;97(5):999–1014.
64. Spinella PC, Holcomb JB. Resuscitation and transfusion principles for traumatic hemorrhagic shock. Blood Rev 2009;23(6):231–40.
65. American College of Obstetricians and Gynecologists. ACOG practice bulletin: clinical management guidelines for obstetrician-gynecologists number 76, October 2006: postpartum hemorrhage. Obstet Gynecol 2006;108(4):1039–47.
66. Dacus JV, Dellinger EH, Keiser SD, et al. Preventing maternal death: 10 clinical diamonds. Obstet Gynecol 2012;120(1):179–80 [author reply: 180].
67. Butwick AJ, Goodnough LT. Transfusion and coagulation management in major obstetric hemorrhage. Curr Opin Anaesthesiol 2015;28(3):275–84.
68. Rossaint R, Bouillon B, Cerny V, et al. The European guideline on management of major bleeding and coagulopathy following trauma: fourth edition. Crit Care 2016;20:100.
69. Roberts I, Shakur H, Coats T, et al. The CRASH-2 trial: a randomised controlled trial and economic evaluation of the effects of tranexamic acid on death, vascular occlusive events and transfusion requirement in bleeding trauma patients. Health Technol Assess 2013;17(10):1–79.
70. Pacheco LD, Hankins GDV, Saad AF, et al. Tranexamic acid for the management of obstetric hemorrhage. Obstet Gynecol 2017;130(4):765–9.
71. Kikuchi J, Deering S. Cardiac arrest in pregnancy. Semin Perinatol 2018;42(1):33–8.
72. Kee WDN. The use of vasopressors during spinal anaesthesia for caesarean section. Curr Opin Anaesthesiol 2017;30(3):319–25.
73. Haas DM, Benjamin T, Sawyer R, et al. Short-term tocolytics for preterm delivery: current perspectives. Int J Womens Health 2014;6:343–9.
74. American College of Obstetricians and Gynecologists' Committee on Practice Bulletins—Obstetrics. Practice bulletin no. 171: management of preterm labor. Obstet Gynecol 2016;128(4):e155–64.
75. Gyamfi-Bannerman C, Thom EA. Antenatal betamethasone for women at risk for late preterm delivery. N Engl J Med 2016;375(5):486–7.
76. American College of Emergency Physicians Clinical Policies Subcommittee on Early Pregnancy, Hahn SA, Promes SB, Brown MD. Clinical policy: critical issues in the initial evaluation and management of patients presenting to the emergency department in early pregnancy. Ann Emerg Med 2017;69(2):241–50.e20.
77. Hui D, Morrison LJ, Windrim R, et al. The American Heart Association 2010 guidelines for the management of cardiac arrest in pregnancy: consensus recommendations on implementation strategies. J Obstet Gynaecol Can 2011; 33(8):858–63.
78. Seamon MJ, Haut ER, Van Arendonk K, et al. An evidence-based approach to patient selection for emergency department thoracotomy: a practice

management guideline from the Eastern Association for the Surgery of Trauma. J Trauma Acute Care Surg 2015;79(1):159–73.
79. Jeejeebhoy FM, Zelop CM, Lipman S, et al. Cardiac arrest in pregnancy: a scientific statement from the American Heart Association. Circulation 2015; 132(18):1747–73.
80. Trauma during pregnancy. ACOG technical bulletin number 161–November 1991. Int J Gynaecol Obstet 1993;40(2):165–70.
81. Katz V, Balderston K, DeFreest M. Perimortem cesarean delivery: were our assumptions correct? Am J Obstet Gynecol 2005;192(6):1916–20 [discussion: 1920–1].
82. Katz VL. Perimortem cesarean delivery: its role in maternal mortality. Semin Perinatol 2012;36(1):68–72.
83. Katz VL, Dotters DJ, Droegemueller W. Perimortem cesarean delivery. Obstet Gynecol 1986;68(4):571–6.
84. Whitten M, Irvine LM. Postmortem and perimortem caesarean section: what are the indications? J R Soc Med 2000;93(1):6–9.
85. Kvarnstrand L, Milsom I, Lekander T, et al. Maternal fatalities, fetal and neonatal deaths related to motor vehicle crashes during pregnancy: a national population-based study. Acta Obstet Gynecol Scand 2008;87(9):946–52.
86. Ali J, Yeo A, Gana TJ, et al. Predictors of fetal mortality in pregnant trauma patients. J Trauma 1997;42(5):782–5.
87. Hoff WS, D'Amelio LF, Tinkoff GH, et al. Maternal predictors of fetal demise in trauma during pregnancy. Surg Gynecol Obstet 1991;172(3):175–80.
88. Dahmus MA, Sibai BM. Blunt abdominal trauma: are there any predictive factors for abruptio placentae or maternal-fetal distress? Am J Obstet Gynecol 1993; 169(4):1054–9.
89. Goodwin TM, Breen MT. Pregnancy outcome and fetomaternal hemorrhage after noncatastrophic trauma. Am J Obstet Gynecol 1990;162(3):665–71.
90. American College of Obstetricians and Gynecologists. ACOG Practice Bulletin No. 106: intrapartum fetal heart rate monitoring: nomenclature, interpretation, and general management principles. Obstet Gynecol 2009;114(1):192–202.
91. Weiner E, Gluck O, Levy M, et al. Obstetric and neonatal outcome following minor trauma in pregnancy. Is hospitalization warranted? Eur J Obstet Gynecol Reprod Biol 2016;203:78–81.
92. Shinde GR, Vaswani BP, Patange RP, et al. Diagnostic performance of ultrasonography for detection of abruption and its clinical correlation and maternal and foetal outcome. J Clin Diagn Res 2016;10(8):QC04–7.
93. Kopelman TR, Bogert JN, Walters JW, et al. Computed tomographic imaging interpretation improves fetal outcomes after maternal trauma. J Trauma Acute Care Surg 2016;81(6):1131–5.
94. Saphier NB, Kopelman TR. Traumatic Abruptio Placenta Scale (TAPS): a proposed grading system of computed tomography evaluation of placental abruption in the trauma patient. Emerg Radiol 2014;21(1):17–22.
95. EL Kady D, Gilbert WM, Xing G, et al. Maternal and neonatal outcomes of assaults during pregnancy. Obstet Gynecol 2005;105(2):357–63.
96. Sperry JL, Casey BM, McIntire DD, et al. Long-term fetal outcomes in pregnant trauma patients. Am J Surg 2006;192:715–21.
97. Wolf EJ, Mallozzi A, Rodis JF, et al. The principal pregnancy complications resulting in preterm birth in singleton and twin gestations. J Matern Fetal Med 1992;14: 2016–212.

98. Luley T, Fitzpatrick CB, Grotegut CA, et al. Perinatal implications of motor vehicle accident trauma during pregnancy: identifying populations at risk. Am J Obstet Gynecol 2013;208(6):466.e1-5.
99. Klinich KD, Flannagan CA, Rupp JD, et al. Fetal outcome in motor-vehicle crashes: effects of crash characteristics and maternal restraint. Am J Obstet Gynecol 2008;198(4):450.e1-9.
100. Vivian-Taylor J, Roberts CL, Chen JS, et al. Motor vehicle accidents during pregnancy: a population-based study. BJOG 2012;119(4):499–503.
101. Weiss HB, Lawrence B, Miller T. Prevalence and risk of hospitalized pregnant occupants in car crashes. Annu Proc Assoc Adv Automot Med 2002;46:355–66.
102. Schiff MA. Pregnancy outcomes following hospitalisation for a fall in Washington State from 1987 to 2004. BJOG 2008;115(13):1648–54.
103. McCrory JL, Chambers AJ, Daftary A, et al. Dynamic postural stability during advancing pregnancy. J Biomech 2010;43(12):2434–9.
104. Mendez-Figueroa H, Dahlke JD, Vrees RA, et al. Trauma in pregnancy: an updated systematic review. Am J Obstet Gynecol 2013;209(1):1–10.
105. Oxford CM, Ludmir J. Trauma in pregnancy. Clin Obstet Gynecol 2009;52(4):611–29.
106. Beydoun HA, Tamim H, Lincoln AM, et al. Association of physical violence by an intimate partner around the time of pregnancy with inadequate gestational weight gain. Soc Sci Med 2011;72(6):867–73.
107. Tinker SC, Reefhuis J, Dellinger AM, et al. Epidemiology of maternal injuries during pregnancy in a population-based study, 1997-2005. J Womens Health (Larchmt) 2010;19(12):2211–8.
108. Gazmararian JA, Petersen R, Spitz AM, et al. Violence and reproductive health: current knowledge and future research directions. Matern Child Health J 2000;4(2):79–84.
109. Meuleners LB, Lee AH, Janssen PA, et al. Maternal and foetal outcomes among pregnant women hospitalised due to interpersonal violence: a population based study in Western Australia, 2002-2008. BMC Pregnancy Childbirth 2011;11:70.
110. Quinlivan JA, Evans SF. A prospective cohort study of the impact of domestic violence on young teenage pregnancy outcomes. J Pediatr Adolesc Gynecol 2001;14(1):17–23.
111. Njoku OI, Joannes UO, Christian MC, et al. Trauma during pregnancy in a Nigerian setting: patterns of presentation and pregnancy outcome. Int J Crit illn Inj Sci 2013;3(4):269–73.
112. Maghsoudi H, Samnia R, Garadaghi A, et al. Burns in pregnancy. Burns 2006;32(2):246–50.
113. Subrahmanyam M. Burns during pregnancy: effect on maternal and foetal outcomes. Ann Burns Fire Disasters 2006;19(4):177–9.
114. Rezavand N, Seyedzadeh A. Maternal and foetal outcome of burns during pregnancy in Kermanshah, Iran. Ann Burns Fire Disasters 2006;19(4):174–6.
115. Parikh P, Sunesara I, Lutz E, et al. Burns during pregnancy: implications for maternal-perinatal providers and guidelines for practice. Obstet Gynecol Surv 2015;70(10):633–43.
116. Jain M, Garg AK. Burns with pregnancy: a review of 25 cases. Burns 1993;19(2):166–7.
117. Chama CM, Na'Aya HU. Severe burn injury in pregnancy in Northern Nigeria. J Obstet Gynaecol 2002;22(1):20–2.