Trauma: *Clinical Expert Series* CME

Guidance for Evaluation and Management of Blunt Abdominal Trauma in Pregnancy

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Blunt abdominal trauma is the leading type of traumatic injury in pregnancy, with motor vehicle crashes, falls, and assault being the most common etiologies. Several adverse outcomes can occur in pregnancy, including placental abruption, preterm labor and preterm delivery, uterine rupture, and pelvic fracture. Understanding and integration of key anatomic and physiologic changes in pregnancy are key when evaluating a pregnant trauma patient. Pregnant women should be managed in a medical center with the ability to provide adequate care to both trauma patients—the pregnant woman and fetus. Multiple clinical providers are usually involved in the care of pregnant trauma patients, but obstetric providers should play a central role in the evaluation and management of a pregnant trauma patient given their unique training, knowledge, and clinical skills. An algorithm for management of trauma in pregnancy should be used at all sites caring for pregnant women. An alignment of policies within each system optimizes appropriate triage, integration of care, management, and monitoring of pregnant trauma patients and their fetuses. Ensuring effective protocols for prehospital and hospital treatment, as well as thorough training of involved health care providers, is essential in ensuring that optimal care is provided.

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Significant morbidity and mortality are associated with trauma in pregnancy. The initial assessment can also be challenging without an adequate understanding of the physiologic changes of pregnancy, appropriate studies for evaluation, and interpretation of testing during pregnancy. Furthermore, relatively major injuries may present with no symptoms but be associated with significant fetal morbidity and mortality–highlighting the importance of the obstetrician in a pregnant trauma patient's care. An obstetrician's specialized medical training and background can assist with appropriate interpretation of clinical findings and provide fetal assessment, which can improve outcomes. The best initial treatment for the fetus is the provision of optimal resuscitation of the pregnant woman.

Although trauma has been characterized as the leading nonobstetric cause of death among pregnant women, the vast majority of trauma-in-pregnancy data are retrospective, observational, or case series–based, making it challenging to accurately estimate the incidence of trauma in pregnancy.[1–5] In a systematic review of trauma in pregnancy, Mendez-Figueroa et al[6] summarized existing studies to better assess the incidence and prevalence of various mechanisms of injury. Table 1 lists studies that have estimated the incidence and prevalence of trauma in pregnancy by mechanism.

Conversely, the initial structural approach to the management of a pregnant trauma victim has been

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Mark D. Pearlman discloses that this article briefly discusses an emergency procedure called resuscitative endovascular balloon occlusion of the aorta as a potential future use of controlling massive pelvic hemorrhage. The authors' recommendation is not necessarily to advocate the use this technique/device, but to make readers aware of the potential future use of this type of device in the setting of massive pelvic hemorrhage. The authors have no financial interest in this device or the training of use of the device. The other authors did not report any potential conflicts of interest.

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Table 1. Estimated Incidence and Prevalence of Trauma in Pregnancy by Mechanism of Injury

Type of Injury	Estimated Rate/100,000 Live Births
Blunt abdominal trauma (MVCs*; falls†)[2,3]	260
Penetrating trauma‡	3.3
Domestic violence[7–10]	8,307
Suicide[8,11],§	2
Homicide[9,11],§	3.3

MVC, motor vehicle crash.
Data from Mendez-Figueroa H, Dahlke JD, Vrees RA, Rouse DJ. Trauma in pregnancy: an updated systematic review. Am J Obstet Gynecol 2013;209:1–10.
* Study design: population-based cohort.
† Study design: retrospective case–control.
‡ Includes only penetrating trauma leading to fatalities; adapted from reference 6, using data from reference 12.
§ Study design: retrospective cohort.

based on more reliable controlled studies.[1,2,13,14] An algorithm for management of trauma in pregnancy should be a part of all emergency medical services, trauma centers, emergency departments, and labor and delivery units. In addition, alignment of policies within each system, such as the appropriate location for triage, personnel involvement, chain of command, initial work-up, management, and monitoring of pregnant trauma patients has been advocated to allow a standardized approach to care.[15] Creating such guidelines is integral to quality improvement and almost assuredly reduces morbidity and mortality. Given the broad audience this article intends to reach, the paper has been divided by section to help the reader identify the pertinent areas of interest for them with the overall focus being on the evaluation and management of blunt abdominal trauma in pregnancy.

Trauma in pregnancy is most commonly reported in the last trimester.[16] In published series, pregnant women have almost twice the mortality rate of nonpregnant female trauma patients.[17] The reported risk of fetal death as a result of blunt abdominal trauma is higher than that of the pregnant woman.[1] The risk of fetal injury is elevated with later gestational age, and the risk of fetal death is directly correlated to the severity of maternal injuries.[4] Blunt abdominal trauma is the most common etiology of traumatic injury during pregnancy, accounting for the vast majority of reported events.[4,6] The most frequent cause of blunt abdominal trauma resulting in presentation for clinical care during pregnancy is motor vehicle crashes.[4] "Motor vehicle crash" is the preferred terminology rather than "motor vehicle accident," because motor vehicle crash encompasses a wider range of causality.[18] Consistent seatbelt use has been shown to substantially decrease fetal and maternal morbidity and mortality, with fetal adverse outcome risk-reduction estimates as high as 84% compared with unbelted pregnant women involved in motor vehicle crashes.[19] The second most common cause of blunt abdominal trauma during pregnancy is falls.[5,20] Pregnancy increases the risk of falls owing to weight gain, expansion of the gravid abdomen, and a shift in the center of gravity. As demonstrated by anthropometric models, the ability to control balance during walking decreases after the middle of the second trimester. This change in center of gravity is the likely explanation for the increased incidence of falls in the late second and third trimesters.[4,21] Blunt trauma can also result from assault. Intimate partner violence is one of the most common causes of assault and is reported to affect up to a quarter of pregnancies in some countries.[7,8,22] Assault likely contributes to greater numbers of trauma in pregnancy, but is frequently underreported.[23] Several factors may contribute to underreporting, including fear of retaliation, desire to keep the incident private, and a lack of trust in the reporting system. Owing to underreporting, we support the recommendation that all pregnant women who present with traumatic injury be screened for intimate partner violence.[23] Based on potential risks to the fetus, admission rates after trauma are higher in pregnant trauma patients than in nonpregnant women who suffer trauma.[24] Although most women who require hospital admission will go home undelivered, a small subset of women may deliver during that hospitalization, with placental abruption being the most likely underlying etiology for preterm birth and adverse outcomes.[13,24,25]

PREGNANCY ANATOMY AND PHYSIOLOGY

Pregnancy alters female anatomy and physiology–affecting patterns of injury, as well as physiologic response or adaptation to trauma. All health care

providers involved in the care of pregnant trauma victims should be familiar with these changes (Table 2).

Anatomic Changes

Before the first trimester, the uterus is within the pelvis, and direct injury to the uterus and fetus is unlikely unless pelvic fracture occurs.[26] After that, the uterus becomes an abdominal organ; at 20 weeks of gestation, the uterus is at the level of the umbilicus, and, by 36 weeks, it extends to the costal margin.[27,28] These landmarks are different in multiple gestations. Owing to the progressive increase in the size of the uterus, there is redistribution of the abdominal viscera. Although the maternal abdominal viscera are thought to remain in locations similar to the nonpregnant state for a majority of the first and second trimesters, observational data suggest a 25% increased risk of hepatic or splenic maternal injuries after blunt abdominal trauma in pregnant patients.[29] The enlargement of the uterus during the third trimester makes the fetus potentially more susceptible to direct fetal trauma.[30–32]

Cardiovascular and Hematologic Changes

Cardiac output increases by about 40% during pregnancy owing to increases in both heart rate and stroke volume. Blood pressure (both systolic and diastolic) is decreased in the first trimester and reaches its nadir in the second trimester, with a return to near normal values in the third trimester.[33] By 10 weeks of gestation, maternal blood and plasma volume have increased, by 30% and 50%, respectively. Red blood cell mass increases too, but to a lesser extent, which results in a change in the normal hematocrit–often referred to as *physiologic anemia of pregnancy.* These changes are critical because they provide the pregnant woman with a higher tolerance to hemorrhage. In contrast to the nonpregnant state, signs such as tachycardia, hypotension, or changes in fetal heart rate pattern might not occur until substantial blood loss has occurred (eg, 20% of total blood volume), which can delay identification of hemorrhagic shock.[27,33,34] Acute maternal blood loss due to trauma can result in shunting blood away from the placenta through uterine artery vasoconstriction. Although uncommon, a fetus can experience hypoxemia even with relatively normal maternal vital signs.[35] Owing to the sensitivity of the fetus to even small placental flow changes, maternal blood volume loss can be first manifested by evidence of a nonreassuring fetal heart rate.[28]

The gravid uterus also causes the heart to be shifted and displaced upwards and to the left. This can slightly alter the appearance of chest radiography and electrocardiograms in pregnancy, with findings of left axis deviation, depressed ST segments, and frequent inversion or flattening of the T wave in lead III.[33,36] Beyond approximately 20 weeks of gestation, the gravid uterus also compresses the inferior vena cava, which can lead to decreased venous return and stroke volume and, in turn, decreased cardiac output–a contributor to hypotension. Venous return and cardiac output are improved when the pregnant patient lies

Table 2. Key Physiologic Changes in the Pregnant Trauma Patient

Organ System	Changes in Pregnancy
Cardiovascular	Increased cardiac output
	Increased heart rate*
	Increased stroke volume
	Decreased systemic vascular resistance
	Decreased systolic and diastolic blood pressure in the 1st trimester*†
Hematologic	Physiologic anemia‡
	Increased clotting factors§
	Increased fibrinogen
	Decreased fibrinolysis
Respiratory	Increased minute ventilation‖
	Increased tidal volume‖
	Increased risk of aspiration¶
Gastrointestinal	Decreased gastric motility¶
	Decreased esophageal sphincter tone¶

* Maternal tachycardia and hypotension may be confused with possible hypovolemia.
† Normalizes in the 3rd trimester.
‡ Maternal expanded blood volume, increased plasma volume, and lesser red blood cells have a greater capacity to "hide" significant hemorrhage; also lead to physiologic anemia.
§ Maternal increase in clotting factors significant increases risk of thromboembolic events.
‖ Maternal respiratory changes play a role in appropriate ventilator settings.
¶ Maternal slowed gastric motility increases risk of pulmonary aspiration.

at a 15 to 30-degree leftward tilt to displace the uterus off the inferior vena cava.[23,34] Uterine displacement should be a standard practice for all pregnant trauma victims beyond 20 weeks of gestation to improve venous return and maximize position-related cardiac output changes.

Fibrinolysis is decreased in pregnant women, resulting in greater amounts of fibrinogen and coagulation factors, increasing the susceptibility to venous thromboembolic events during pregnancy.[30] The increased thromboembolic risk is especially important to consider in those pregnant trauma patients who become hospitalized after their initial evaluation and stabilization.

Respiratory Changes

Pregnancy alters maternal respiratory system physiology. The diaphragm becomes progressively elevated, up to 4 cm cephalad from its typical location.[33] Oropharyngeal edema and hyperemia decrease the distance from the tongue to the roof of the mouth (Mallampati score), which increases the likelihood of a difficult airway if intubation is necessary. Pregnancy also results in a decreased total lung capacity, decreased residual volume, increased minute ventilation, and up to 20% increased oxygen consumption. All trauma victims should receive supplemental oxygen owing to the potential for hypoxemia or hemorrhagic shock.[23,37,38] Pulmonary and renal alterations in pregnancy also result in significant changes in maternal arterial pH, pO_2, pCO_2, and bicarbonate (Table 3).

Careful attention to these changes is needed when a pregnant trauma patient requires intubation, not only because of increased risk for a difficult airway, but also the need to adjust ventilator settings to maintain respiratory parameter goals. Awareness of the changes in maternal pH, pO_2, pCO_2, and bicarbonate is important for correctly interpreting an arterial blood gas. For example, if a $paCO_2$ value of 40 mm Hg is seen in a pregnant patient, this may reflect impending respiratory failure or hypoventilation.[30] Decreased maternal $paCO_2$ creates a gradient between maternal and fetal CO_2 that facilitates transfer of CO_2 from the fetus to the pregnant woman. Maternal acidosis needs to be avoided, because it compromises maternal–fetal gas exchange.[27] Treatment for acidosis should involve correction of the underlying process (eg, hypovolemia) and optimizing maternal ventilator settings.

Table 3. Arterial Blood Gas Values: Nonpregnant and Pregnant Patients

Nonpregnant	Pregnant
paCO2 37–40 mm Hg	paCO2 27–32 mm Hg ↓ (respiratory alkalosis)
pH 7.35–7.40	pH 7.40–7.45 ↑
paO2 75–100 mm Hg	PaO2 105 mm Hg ↑
HCO3- 22–26 mmol/L	HCO3− 18–21 mmol/L ↓

Gastrointestinal Changes

Gastric motility and esophageal sphincter tone are decreased during pregnancy, which increases the risk of pulmonary aspiration. The use of a decompressive nasogastric tube may be warranted in the management of a pregnant trauma patient who does not have a protected airway.[34,35] The upper respiratory tract becomes edematous and hyperemic in pregnancy, so particular care should be taken when an orogastric or nasogastric tube is placed to avoid bleeding.[28]

PATTERNS OF TRAUMA

In addition to the changed physiology, pregnancy can alter the patterns of injury resulting from trauma. Pregnant women have higher rates of severe abdominal and extremity injuries compared with nonpregnant women, whereas head injuries are usually less severe.[35] As pregnancy advances and the uterus occupies a larger volume of the intraabdominal cavity, energy absorbed by the uterus may result in direct injuries to the uterus and fetus.[4,39] Most importantly, there can be indirect injury to the uteroplacental interface (eg, abruptio placentae).[4,39]

Placental Abruption

Placental abruption is the leading obstetric serious adverse event resulting from blunt abdominal trauma in pregnancy.[39,40] In blunt trauma, energy absorbed by the muscular and elastic uterus is also transmitted to the more rigid placenta. These differences in tissue property can create a shearing force at the uteroplacental interface. This shearing force can result in disruption of the attachment, which is the major mechanism of abruptio placenta complicating trauma in pregnancy.[13] Placental abruption of clinical significance usually presents within hours after the initial traumatic event. Symptoms may include uterine tenderness, uterine contractions, vaginal bleeding, maternal hypotension, or nonreassuring fetal heart tones. Uterine contractions are the single most important predictor of placental abruption. Use of tocometry for a minimum of 2–4 hours after trauma is highly sensitive for detection of placental abruption and important in the assessment of pregnant trauma

patients.[13,39] Uterine contractions in the setting of trauma are nonspecific; only 14.3% of women who are contracting regularly (defined as contractions every 2–5 minutes) during the recommended monitoring period will actually have a clinically significant placental abruption.[13,39] Abruption of the placenta can lead to premature birth, premature rupture of membranes, fetal hypoxemia, fetal death, and maternal disseminated intravascular coagulation.[35,40] Ultrasonography can be helpful in distinguishing a placental abruption from other pathology. Although the sensitivity of obstetric ultrasonography has improved over time, it should be considered as supplementary to tocometry during the patient's evaluation.[41–43] Ultrasonographic findings for a placental abruption can include, but are not limited to, retroplacental hematoma, separation of membranes from the uterine wall, and anechoic spaces within the placenta.[41,43] Other imaging modalities, such as magnetic resonance imaging, have been shown to be more sensitive than ultrasonography for the detection of placental abruption. However, magnetic resonance imaging is less practical and typically is not used in the evaluation of a trauma patient for placental abruption.[44]

It may be pertinent to obtain a coagulation profile in some pregnant trauma patients (Figs. 1 and 2). Decreased fibrinogen levels (eg, less than 200 mg/dL) can suggest development of disseminated intravascular coagulation, which can be seen with the diagnosis of placental abruption.[30] Rotational thromboelastometry, which allows for dynamic monitoring of coagulopathy, is being used at some institutions during management of obstetric hemorrhage. Rotational thromboelastometry examines the kinetics of hemostasis by assessing clotting time, clot formation, clot stability and clot lysis.[45] It can be performed and interpreted at bedside within minutes by health care providers trained in its use and can help practitioners better understand the evolving clinical situation, especially if there is concern for placental abruption and disseminated intravascular coagulopathy.[45]

Pelvic Fracture

The incidence of any bone fracture with trauma in pregnancy is relatively low (less than 1%). Of these, only about 1 in 20 are pelvic fractures.[25,26] The presence of pelvic fractures in pregnant trauma victims has been associated with higher morbidity and mortality in both the pregnant woman and the fetus (eg, fetal skull fracture).[46] Pelvic fracture stabilization can be performed using invasive or noninvasive techniques.[47] Pelvic fractures are not normally an indication for cesarean delivery, especially if stable, and vaginal delivery can be safely attempted in most cases.[26,48] However, given the importance of the mobility of the symphysis and sacroiliac joints during delivery, patients who have had fixation across the pubic symphysis or sacroiliac joints can have interference with an attempt at a vaginal birth and a higher risk of cesarean delivery.[47]

Uterine Rupture

Uterine rupture occurs in less than 1% of trauma during pregnancy, with the most significant risk factor being a history of prior cesarean birth. Maternal mortality has been reported to be as high as 10%, and the fetal mortality rate approaches 100% if uterine rupture occurs in the setting of trauma.[40] Findings on physical examination can include abdominal tenderness, vaginal bleeding, nonreassuring fetal heart rate, palpation of fetal parts on abdominal examination, and an irregularly shaped uterus. Treatment for a uterine rupture is exploratory laparotomy, delivery of the fetus, and uterine repair or hysterectomy.[30,35]

Rupture of Membranes, Preterm Labor, and Preterm Birth

If rupture of membranes (ROM) occurs as a result of trauma, the greatest risk to the fetus is preterm birth. Evaluation for rupture of membranes should occur if there are symptoms of leakage or vaginal bleeding. If, after trauma, a patient presents with altered mental status, an ultrasound or sterile speculum examination, or both should be performed to assess for rupture of membranes. Premature labor has been reported to be more likely in pregnant women experiencing trauma compared with those with no history of trauma.[25] Although many previous recommendations argued against the use of tocolytics in the presence of a trauma patient with uterine contractions, if membranes are intact and clinical suspicion of a placental abruption is low, the short-term administration of tocolytics such as indomethacin or nifedipine may be considered particularly to enable the administration of corticosteroids.[30,39] Magnesium sulfate can also be given for the benefit of neuroprotection to women at risk of preterm labor before 32 weeks of gestation.[49] If significant contractions or a high suspicion for preterm delivery is present, a course of corticosteroids (typically betamethasone 12 mg intramuscularly, two doses 24 hours apart) should be administered.[50] Beta mimetics should be avoided as a tocolytic, because they can cause a change in vital signs–including tachycardia and

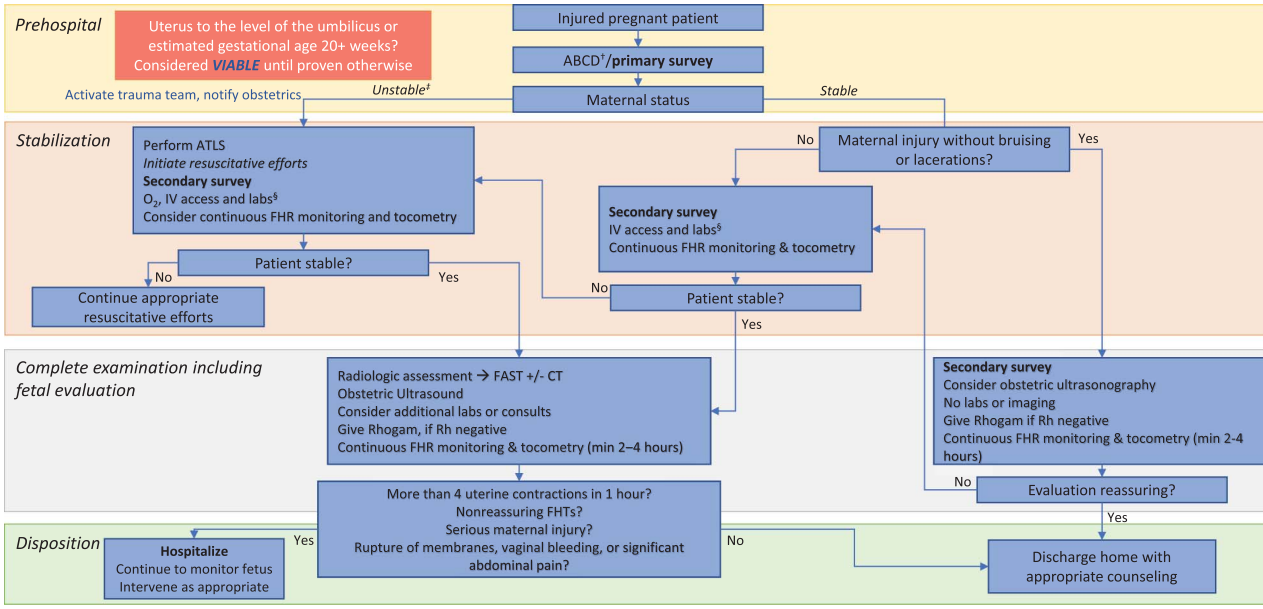

Fig. 1. Evaluation and management of trauma in pregnancy in viable* gestations. *Viable defined as 22–24 weeks of gestation; varies by region. †ABCD: airway, breathing, circulation, displacement (ensure left lateral tilt of patient). ‡Unstable: cardiac arrest, unresponsive, loss of airway or respiratory arrest, blood pressure less than 80/40 or heart rate less than 50 or greater than 140 beats per minute (bpm), viable fetus with fetal heart rate (FHR) less than 110 or greater than 160 bpm. §Laboratory values: if unstable: complete blood count, coagulation profile, fibrinogen, fetal maternal hemorrhage screen, type and screen, creatinine±arterial blood gas; if stable: complete blood count, coagulation profile, fibrinogen, fetal maternal hemorrhage screen, type and screen. ATLS, *Advanced Trauma Life Support*; IV, intravenous; FAST, focused abdominal sonography for trauma; CT, computed tomography; FHT, fetal heart tone.

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hypotension–which can confound the assessment of hypovolemia in the setting of trauma.[51]

Amniotic Fluid Embolism

Amniotic fluid embolism (AFE) is a rare but potentially devastating consequence of maternal trauma. The pathophysiology of why AFE occurs is not completely understood, but it is historically thought to be due to a breach between the maternal and fetal placental barrier (abruptio placentae) allowing amniotic fluid to enter the maternal circulation.[52] No definitive method of confirming an AFE exists, but an AFE should be suspected or considered clinically if there is a sudden and unexplainable development of maternal hypotension and hypoxemia, particularly in the setting of disseminated intravascular coagulation or multiorgan failure. The treatment for an AFE is supportive care, and delivery should be considered in the setting of trauma.[52]

INTERDISCIPLINARY CARE

Usually many health care providers and different specialties are involved in the care of a pregnant trauma patient. Therefore, an integrated and coordinated approach to team management is needed to optimize maternal and fetal outcomes. Effective team-based care requires coordination by a team leader, which should generally be an emergency physician or trauma surgeon.[23] This leader needs to ensure prioritization of interventions, closed-loop communication, and ongoing assessment with the other care providers.[23] It has been demonstrated that the use of simulation can identify and correct common clinical errors made during emergencies, including obstetric trauma evaluations.[53,54] Simulation can help ensure a standardized approach to the interdisciplinary care provided for pregnant trauma patients. Policies should be in place in all health care systems that take care of these patients to ensure there is a standardized approach each time a pregnant trauma victim presents. A checklist may help standardize patient care.[55]

Prehospital Decision Making

Emergency medical services professionals are often the first to interact with a trauma victim. These individuals should maintain the same guidelines for initial evaluation and management as they would for a nonpregnant patient. When treating pregnant trauma victims, the initial focus should be on

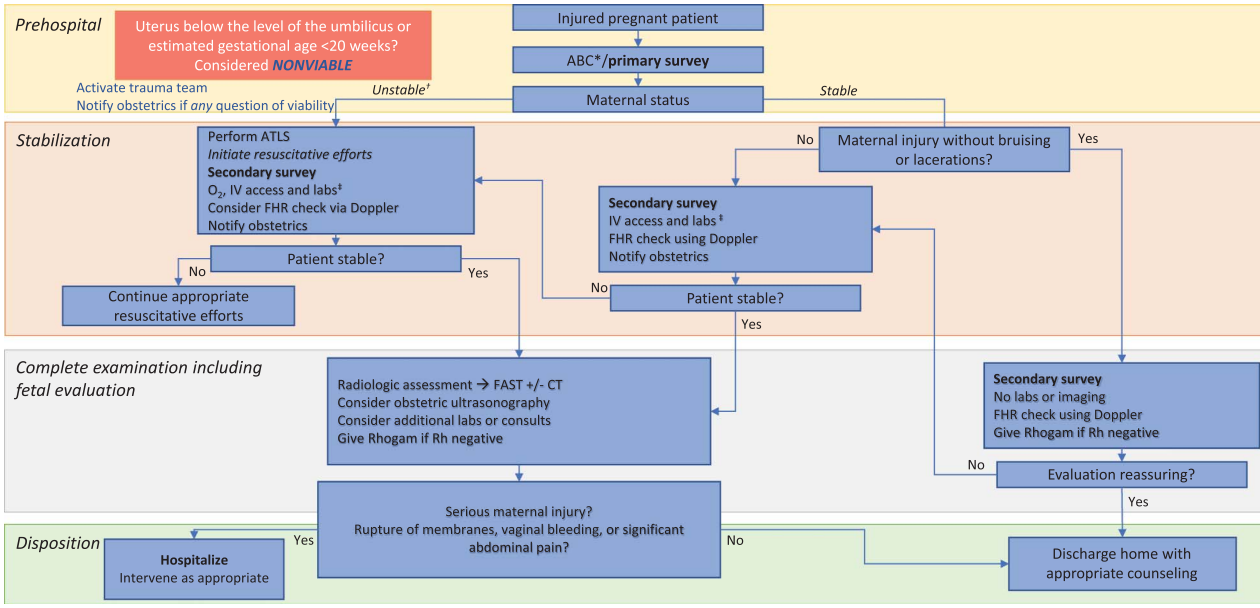

Fig. 2. Evaluation and management of trauma in pregnancy in nonviable gestations. *ABC: airway, breathing, circulation. †Unstable: cardiac arrest, unresponsive, loss of airway or respiratory arrest, blood pressure less than 80/40 or heart rate less than 50 or greater than 140 beats per minute (bpm), viable fetus with fetal heart rate (FHR) less than 110 or greater than 160 bpm. ‡Laboratory values: if unstable: complete blood count, coagulation profile, fibrinogen, fetal maternal hemorrhage screen, type and screen, creatinine±arterial blood gas; if stable: complete blood gas, coagulation profile, fibrinogen, fetal maternal hemorrhage screen, type and screen. ATLS, *Advanced Trauma Life Support*; IV, intravenous; FAST, focused abdominal sonography for trauma; CT, computed tomography.

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maternal stability, and the basic *Advanced Trauma Life Support* algorithm should be followed: airway, breathing, circulation, disability, and exposure (ABCDE). Once maternal stability is assured, focus can be placed on the fetus.[23] Although "D" stands for "disability" in the *Advanced Trauma Life Support* protocol, in the obstetric trauma patient, "D" also stands for "displacement." If a pregnant trauma patient is in the second half of pregnancy (estimated if the uterus is palpable at or above the umbilicus), the gravid uterus should be displaced 15–30 degrees off the main retroperitoneal blood vessels, usually through a left lateral tilt, to improve central circulating volume and cardiac output. A simple technique is to place a 4–6-inch towel roll under the right side of the backboard, or, alternatively, manual displacement of the uterus to the left.

The pregnant trauma patient should always be brought to the nearest facility capable of stabilizing her and taking care of both pregnant woman and fetus. In particular, the Centers for Disease Control and Prevention's Field Triage Guidelines recommend that pregnant patients at more than 20 weeks of gestation be transported to a trauma center.[56] Regional emergency medical services units should have established protocols within their area that addresses how to best triage and manage a pregnant patient. The emergency department is typically notified about an incoming trauma through an emergency medical services call. It is important that an estimate of fetal gestational age is provided at the time of the call so that the appropriate members of the trauma team are notified. Depending on the cause of trauma and the gestational age of the fetus, different health care providers are notified and asked to be present either at the time of the patient's arrival or shortly thereafter.

Trauma Center Levels

Level I is considered to be the highest level of care for a trauma center. In the United States, the levels range from level I to level V based on a designation process at the state or local level, and a verification process done by the American College of Surgeons (Table 4). In their definitions of trauma levels, the American College of Surgeons states that an obstetrician has to be available (but not necessarily in-house) at a level I center.[58]

Table 4. Trauma Centers by Level Based on American College of Surgeons Trauma Center Verification Criteria

Trauma Center Level by ACS Verification	In-House Coverage 24/7/365				Tertiary* Care	Has Ability to Provide Advanced Trauma Life Support
	General Surgery	Anesthesiology	Emergency Medicine	Critical Care or Intensive Care Capability		
I	Yes	Yes	Yes	Yes	Yes	Yes
II	Yes	Yes	Yes	Yes	No	Yes
III	No	No	Yes	Yes	No	Yes
IV	No	No	No	No	No	Yes
V	No	No	No	No	No	No

ACS, American College of Surgeons.

Data from American Trauma Society. Trauma center levels explained. Available at: www.amtrauma.org/page/traumalevels. Retrieved March 2, 2019 *and* data from Committee on Trauma. American College of Surgeons. Resource for optimal care of the injured patient. Available at: https://www.facs.org/quality-programs/trauma/tqp/center-programs/vrc/resources. Retrieved September 23, 2019.

* Highly specialized medical care that involves advanced and complex procedures and treatments performed by medical specialists in state-of-the-art facilities.

Policies

In our region, the ambulance services that work within the county have specific protocols that are used in the triage and management of trauma and obstetric patients.[59] They follow the Centers for Disease Control and Prevention's Field Triage Guidelines for transporting any pregnant patient at more than 20 weeks of gestation to a trauma center.[60] Once in the emergency department at our institution, there are specific trauma protocols in place for physicians and nurses in the management of obstetric trauma patients. These are uniform policies across the system, because, often times, minor trauma patients will present to labor and delivery rather than to the emergency department for evaluation. If a pregnant trauma patient presents to the emergency department and is at less than 20 weeks of gestation, an obstetrics and gynecology resident is notified of the arrival. However, if the patient is at more than 20 weeks of gestation, the "birth center" emergency pager system is activated, notifying in-house obstetric providers that they are needed in the emergency department immediately. Neonatal care providers are also notified through this pager system. The birth center emergency pager system prompts early, quick, and uniformly standardized involvement of the obstetric team in the pregnant trauma patient's care. A written policy and standardized approach allow the entire team (emergency, trauma, and obstetrics) to anticipate timely placement of fetal and uterine monitoring and defines the roles of the various team members.

STANDARDIZED CARE AND MANAGEMENT

Over the past 30 years, continuous fetal monitoring and tocometry became routine management after trauma in pregnancy with a viable fetus.[13,61] Figures 1 and 2 provide overviews of the recommended steps in the evaluation and management of pregnant trauma patients dependent on fetal viability.

Primary Survey

A complete primary survey and maternal stabilization should precede any fetal assessment. The first priority should be to optimize maternal hemodynamics and oxygenation. The best initial treatment for the fetus is the provision of optimal resuscitation of the pregnant woman. Fetal assessment should occur with the secondary survey.[35]

Standard trauma assessment uses the ABCDEs (airway, breathing, circulation, disability or displacement, exposure).[23] The patent's airway needs to be assessed first. Supplemental oxygen by nonrebreather mask at FiO_2 1.0 should be administered and breath sounds should be confirmed bilaterally. Cardiovascular assessment follows immediately focusing on the presence or absence of hypovolemic shock (Table 5). Because pregnant patients have an increased plasma volume and cardiac output, significant blood loss can take place before signs of hypovolemic hemorrhagic shock (tachycardia, hypotension) occur. Intravenous (IV) access should be established using two large bore IVs, and IV fluids or blood products may be administered.[23] There have been no large trials comparing restrictive compared with liberal fluid administration in blunt trauma, but slower infusions are generally favored over rapid boluses, because slower infusions are thought to minimize intraabdominal bleeding while maintaining adequate organ perfusion.[63] The *Advanced Trauma Life Support* protocol recommends use of crystalloid fluid for resuscitation and early type-specific

Table 5. Classes of Hemorrhagic Shock

Parameter	Class I	Class II (Mild)	Class III (Moderate)	Class IV (Severe)
Approximate blood loss	< 15%	15–30%	31–40%	> 40%
Heart rate	↔	↔/↑	↑	↑/↑↑
Blood pressure	↔	↔	↔/↓	↓
Pulse pressure	↔	↓	↓	↓
Respiratory rate	↔	↔	↔/↑	↑
Urine output	↔	↔	↓	↓↓
Glasgow coma scale score	↔	↔	↓	↓
Base deficit[a]	0 to −2 mEq/L	−2 to −6 mEq/L	−6 to −10 mEq/L	−10 mEq/L or less
Need for blood products	Monitor	Possible	Yes	Massive transfusion protocol

[a] Base excess is the quantity of base (HCO3–, in mEq/L) that is above or below the normal range in the body. A negative number is called a *base deficit* and indicates metabolic acidosis.

Reprinted with permission from American College of Surgeons. Advanced trauma life support. 10th Ed. Chicago, IL: American College of Surgeons; 2018 *and* data from Ballas J, Roberts S. Hypovolemic shock. In: Phelan JP, Pacheco LD, Foley MR, Saade GR, Dildy GA, Belfort MA, editors. Critical Care Obstetrics. 6th ed. Hoboken (NJ): Wiley; 2018:535-46.

blood.[23] For hemorrhagic shock, provide only 1 L of isotonic crystalloid fluid before moving to blood product administration if the patient is not adequately responding. Initiate a massive transfusion protocol (1:1:1 blood product resuscitation of plasma, platelets, and red blood cells to mimic whole blood) for patients with severe hemorrhagic shock.[64] Definitive control of ongoing hemorrhage is a high priority. Vasopressors should be a last resort for supporting maternal blood pressure because these agents reduce uterine blood flow, which can result in fetal hypoxemia.[23] Per *Advanced Trauma Life Support*, tranexamic acid (1 g bolus IV over 10 minutes, then 1 g IV infusion over 8 hours) is recommended for treatment of hemorrhagic shock if diagnosed within 3 hours of injury.[23] Assessment and early treatment of trauma-induced coagulopathy with viscoelastic testing (eg, rotational thromboelastometry) can be performed if available, because goal-directed hemostatic resuscitation is associated with increased survival and decreased blood product usage in trauma resuscitation.[65]

After initiating appropriate fluid resuscitation, the patient's spine is stabilized before being placed in a leftward tilt, displacing the uterus to the left and off the aortocaval vessels to maximize cardiac output. A rapid neurologic assessment should also take place and the patient should be log-rolled to identify any obvious injuries on the posterior portions of the body.[23]

Secondary Survey

The secondary survey should include a complete physical examination. This is also the time when the obstetrician should become actively involved in the patient's care, evaluation, and fetal assessment. Key components of the history should include gestational age, parity, mode of prior deliveries, and any complications in the pregnancy thus far. Early initiation of continuous electronic fetal monitoring and tocometry is the most important way to assess uterine activity and for signs of fetal tachycardia or bradycardia, fetal death, or a nonreassuring fetal tracing, any of which may be an important indicator of placental abruption.[13,39] Bedside ultrasound examination of the fetus can also be considered at this time. Key components of the physical examination should include an abdominal examination and consideration of a pelvic examination if there are symptoms or signs of vaginal bleeding or rupture of membranes.

Trauma Laboratory Evaluation

Dependent on the severity of maternal injury, routine laboratory evaluation should be performed, including a complete blood count, serum creatinine, type and screen, fetal maternal hemorrhage screen, fibrinogen level, and coagulation profile. If the patient had a significant mechanism of injury or is unstable, an arterial blood gas should also be obtained.

The Kleihauer Betke test has been used to evaluate the presence of fetal maternal hemorrhage. Traditionally, collection of the Kleihauer Betke test has been recommended on all pregnant trauma patients, irrespective of their Rh status. More recently, however, this test has not been uniformly recommended, because flow cytometry has emerged as the preferred technique for assessing fetal maternal hemorrhage in all Rh positive and Rh negative patients.[66] Data suggest that flow cytometric assessment of fetal maternal hemorrhage is superior to Kleihauer Betke because it is more sensitive and timely for the quantification of fetal maternal hemorrhage.[67] However, all pregnant trauma patients who are Rho(D) negative should be given Rho(D) immune globulin, regardless

of a positive or negative fetal maternal hemorrhage screen, unless the injury was remote from the uterus (eg, isolated distal extremity injury without fall).[23] Rho(D) immune globulin should be given to Rho(D) negative pregnant women within 72 hours of injury.[23] The typical dose of Rho(D) immune globulin is 300 micrograms intramuscular injection, which provides protection against Rh isoimmunization of ~30 mL of fetal blood in the maternal circulation.[68] If a larger bleed is detected by flow cytometry or Kleihauer-Betke, additional Rho(D) immune globulin should be administered and appropriate fetal assessment should take place.

Respiratory Support

If intubation is required, adequate preoxygenation and rapid sequence (drug-assisted) intubation with application of cricoid pressure should be performed. All pregnant trauma patients should be considered to have difficult airways until proven otherwise. Ideally, a video laryngoscope, flexible fiberoptic bronchoscope, and a very experienced health care provider (eg, anesthesiologist) should be available for the procedure. Either an oral or nasal approach for intubation can be considered. Generally, an oral approach is preferred.[69] Once the pregnant trauma patient is intubated, she should be hyperventilated to maintain respiratory alkalosis with a target pCO_2 appropriate for stage of pregnancy (eg, pCO_2 30 mm Hg). An orogastric tube should be placed after intubation for gastric decompression to prevent aspiration, because the risk is increased owing to decreased lower esophageal sphincter tone and increased intraabdominal pressure from the gravid uterus.[70]

Ultrasonography should be used to identify pneumothorax, although chest X-ray may also be used if there is no experienced ultrasound provider available. Given the elevation of the diaphragm during pregnancy, if pneumothorax or hemothorax treatment with tube thoracotomy is required, it should be performed with real-time ultrasound guidance. The chest tube should be inserted one to two intercostal spaces above the commonly used fifth intercostal space to avoid potential abdominal injury.[37]

Imaging

Obstetric ultrasound examination usually plays a role in the evaluation of pregnant trauma patients. Obstetricians can quickly assess the presence of fetal heart tones, estimated gestational age, placental location, findings suggestive of abruptio placentae, and amniotic fluid volume with a bedside scan.

A focused abdominal sonography for trauma, or FAST examination, is extremely useful in assessing for intraabdominal bleeding owing to its safety, test performance, and noninvasive nature. It can identify the presence of free fluid and may also suggest the presence of solid organ injury.[4] The FAST examination in pregnant trauma patients was found to detect intraperitoneal fluid with a sensitivity, specificity, and accuracy similar to that of nonpregnant patients in two small single-institution studies of 127 and 102 patients.[71,72] However, in the largest study to date (328 pregnant patients), FAST sensitivity was only 61%, with specificity of 94.4% and accuracy of 92.1%–suggesting that FAST may be less sensitive in pregnant patients for abdominal injury, but remains highly specific.[73] Equivocal FAST examination results (eg, being uncertain whether intraperitoneal fluid is present) require alternative imaging techniques to identify traumatic injuries and facilitate appropriate and prompt treatment.

Further radiographic imaging in pregnancy often generates concern for radiation-induced injury to the fetus compared with risk of missing maternal injury. Fetal harm due to radiation depends to a large extent on the gestational age of exposure. The most vulnerable time period is less than 15 weeks of gestation owing to potential disruption of normal organogenesis and fetal brain development in the face of high ionizing radiation dose. An important guiding principle for the use of ionizing radiation is if X-rays are clinically necessary to assess for maternal injury, the indications for imaging should be the same as for a nonpregnant trauma patient and should not be eliminated or delayed.[34] If imaging with ionizing radiation is recommended, the uterus should be shielded. Radiation exposure of less than 50 mGy appears to be safe at any point of pregnancy.[74] A computed tomography scan will often be the quickest, most accessible diagnostic imaging modality for abdominal or pelvic trauma and is considered safe in pregnancy (eg, fetal dose of abdominal computed tomography 1.3–35 mGy).[74] Magnetic resonance imaging is deemed safe at any stage of pregnancy, but accessibility, length of examination, and location of the machine can preclude its feasibility in a trauma patient.

Fetal Viability and Monitoring

The gestational age for which full resuscitative measures are performed for a neonate vary regionally and by institution. In general, the lower limit of viability is considered to be between 22 and 24 weeks of

gestation.[75,76] In cases where gestational age is unknown owing to the absence of an accurate history, a general rule of thumb is that, if the uterus is to the level of the umbilicus, the pregnancy may be viable and fetal monitoring should be initiated until more specific gestational age information can be obtained.[39] In patients with a viable pregnancy who have suffered minor trauma (eg, minor bruising, laceration, contusion) and without the presence of any significant maternal injury, fetal monitoring with both tocodynamometry and fetal heart tones for 4 hours appears to be sufficient.[13,39] Monitoring should be extended to at least 24 hours if uterine contractions, uterine tenderness, vaginal bleeding, rupture of membranes, nonreassuring fetal heart rate patterns, or more extensive maternal trauma are present.[23] The location of prolonged monitoring depends on the extent of maternal injury, and fetal monitoring should be continued if applicable in the emergency department, operating room, intensive care unit, or obstetric unit.[35]

Operative Interventions

The decision to proceed with an operative intervention in trauma, such as exploratory laparotomy, should not be altered because of pregnancy. Indications for exploratory laparotomy include identification of injury, need for repair or reconstruction of injured organs, and hemorrhage control.[35] Indications for an emergency cesarean delivery include a potentially viable pregnancy with maternal death or cardiac arrest, loss of fetal well-being in a viable fetus, uterine rupture, massive hemorrhage–shock, maternal injury where the gravid uterus causes mechanical limitation for repair, threat to life owing to exsanguination from any cause, or unstable thoracolumbar spinal injury.[4,68] If laparotomy is indicated, an obstetrician should be present to assist with both the decision-making and uterine or reproductive tract surgery if needed. If delivery of the fetus is anticipated, a neonatologist (or alternate newborn care provider) should also be contacted immediately to be available and present with the resources needed to resuscitate the neonate.[27]

Cardiopulmonary Resuscitation

In 2015, the American Heart Association updated its guidelines for management of cardiopulmonary resuscitation in adults, including cardiac arrest in pregnancy.[77] Previously, emphasis was on ensuring a clear airway, whereas high-quality chest compression currently takes priority. A useful mnemonic for the pregnant woman who has suffered cardiac arrest is CACDE–compression, airway, circulation, defibrillation, extraction. Extraction refers to delivery of the fetus.[77] Chest compressions during pregnancy beyond 20 weeks of gestation should also take place in a leftward lateral tilt position.[23,77] Although these steps are traditionally taken sequentially, in a pregnant woman, a concurrent approach should be considered. Chest compressions should be performed by multiple members of the response team and health care providers should be rotated out every 2 minutes to optimize quality of compressions.[77]

The *Advanced Trauma Life Support* 10th Edition includes a new algorithm for the management of patients presenting in traumatic circulatory arrest, with initial management including closed chest cardiopulmonary resuscitation, intubation, resuscitation, epinephrine, and finally, bilateral chest decompression to decrease chest pressure if there is no return of spontaneous circulation.[23]

Perimortem Cesarean Delivery

When perimortem cesarean delivery occurs in relation to trauma due to a motor vehicle crash, the reported maternal mortality rate is 66%; the fetal mortality rate is much lower at 18.6%.[4] For viable fetuses, outcomes are best when delivery occurs within 5 minutes of maternal arrest; however, there have been fetal survivors delivered after delays as great as 30 minutes.[78] It has been recommended that "perimortem cesarean section should be considered in any moribund pregnant women of ≥24 weeks of gestation."[79] A perimortem cesarean delivery with evacuation of the uterus has been shown in some cases to help achieve return of spontaneous circulation in the pregnant woman when performed less than 5 minutes from time of arrest.[78,80] This time frame may also improve the likelihood of fetal survival. Because of the need to accomplish uterine evacuation quickly, a splash betadine prep is recommended followed by a vertical midline laparotomy extending from the xiphoid to the pubic symphysis followed by a vertical uterine midline incision to avoid injury to the uterine vasculature and to facilitate rapid fetal delivery.[4]

Emerging Technology

Case reports offer insight on new devices that may play a role in the management of some pregnant trauma patients. In particular, the resuscitative endovascular balloon occlusion of the aorta is a means of controlling noncompressive torso hemorrhage and pelvic hemorrhage in the setting of trauma.[81] Although not currently available to all health care providers, use of the resuscitative endovascular

balloon occlusion of the aorta has been described for pregnant trauma patients as a means to augment systolic blood pressure in the setting of impending vascular collapse.[82] Owing to the quick ability of the resuscitative endovascular balloon occlusion of the aorta to tamponade major vessels, this device might play an important role in the future management of pregnant trauma victims.[82]

DISCHARGE AFTER TRAUMA IN PREGNANCY

Before hospital discharge after evaluation for trauma in pregnancy, the patient should be counseled on signs or symptoms that would prompt re-evaluation. These include decreased fetal movement, vaginal bleeding, leakage of fluid, contractions that are increasing in frequency or severity, and new or worsening abdominal pain. We also recommend screening for domestic violence before discharge.[23] If the patient presented after a motor vehicle crash, it is also an opportunity to review appropriate use of seatbelts and other safety restraint systems (eg, airbags).[19,83] There is some reassuring data that women who suffer trauma during pregnancy but who do not have immediate adverse outcomes do not appear to have a higher rate of later maternal or neonatal complications such as preterm birth, differences in Apgar scores, neonatal intensive care unit admissions, or neonatal length of stay compared with a gestational age-matched control group of women without trauma.[13]

INJURY PREVENTION IN PREGNANCY

Motor vehicle crashes are the largest contributor to blunt abdominal trauma in pregnancy. Use of seatbelts in pregnancy ranges widely, and the severity of maternal and fetal injuries sustained in a motor vehicle crash is lower if appropriate safety devices such as seatbelts and airbags are used.[4,19] Women who properly use seatbelts are less likely to suffer severe injuries themselves and have been shown to have an 84% reduction in the risk of adverse fetal outcomes (preterm birth, placental abruption, fetal death).[19] Correct placement and usage of both the lap belt and shoulder harness provides the best protection. The lap belt should be placed under the gravid abdomen and the shoulder harness should be placed between the breasts and over the mid-portion of the clavicle.[19,83] Incorrect placement of the lap belt on top of the gravid abdomen may result in a greater risk of injury to the uterus or fetus in a motor vehicle crash. If the shoulder harness is available and not used, the risk of maternal injury is increased and the uterus has a higher risk of a compression injury.[19,83] All pregnant patients should be provided with instructions on how to correctly wear a seatbelt and shoulder harness, ideally at their first prenatal visit.

It has been theorized that the force associated with rapid airbag deployment is associated with higher rates of placental abruption. However, a retrospective case review suggested that placental abruption from airbag deployment actually occurs with low frequency in women who are properly restrained with seatbelts.[19] Additionally, in a pregnant crash dummy that measured energy transmission to the uterus, airbag deployment did not increase energy transmission, but did decrease the risk of serious maternal facial and thoracic injuries.[19] It is recommended that women also adjust their steering wheels upward towards the face and chest and away from the belly.[19,84]

Domestic violence and intimate partner violence are other areas of concern for safety during pregnancy. Rates of domestic violence vary by study, but have been reported to be as high as 40%.[7–10] The health care provider should be suspicious if there is a history inconsistent with type of injury, frequent visits to the physician, or history of substance abuse. Substance abuse itself represents an increased risk of trauma. Patients with a history of or current substance abuse should be offered intervention to reduce the occurrence of trauma in pregnancy.[23,35]

CONCLUSION

Clinicians who may be involved in the care of a pregnant trauma patient must be aware of the anatomic and physiologic changes that occur in pregnancy, the patterns of injury during pregnancy, methods of fetal assessment, and coordinated management of these patients. Obstetric providers should play a central role in the evaluation of a pregnant trauma victim at the time of the secondary survey. Maternal evaluation, management, and resuscitation should be the health care provider team's primary concern, because these affect fetal survival. Fetal assessment and monitoring should be determined and standardized based on gestational age. Finally, in an effort to reduce the risk of trauma-associated morbidity and mortality, pregnant women should be educated on the proper use of seatbelts and screened for intimate partner violence.

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