Trauma Management in Pregnancy

Gebelikte Travma Yönetimi

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Abstract

Correct, adequate and proper time of care of the pregnant trauma patient is extremely important for both fetal and maternal outcomes. When managing the pregnant trauma victim, one must optimize the well-being of two patients, but the health of the mother is of paramount importance. Rapid assessment, treatment, and transport are critical to optimizing maternal and fetal outcome. Evaluation must be performed with an understanding of the physiologic changes that occur in pregnancy. The basic tenets of trauma evaluation and resuscitation should be applied in maternal trauma. Aggressive resuscitation of the mother is the best management for the fetus. Care must be taken to keep the patient in the left lateral decubitus position to avoid compression of the inferior vena cava and resultant hypotension. Radiographic studies should be used with care. Noninvasive diagnostics should be used when available. Cardiotocographic monitoring of a viable gestation should be initiated as soon as possible in the emergency department to evaluate fetal well-being. Urgent cesarean section should be considered if fetal distress is present or if the presence of the fetus is contributing to maternal instability. This article reviews the critical features necessary in the assessment, diagnosis, treatment, and disposition of pregnant trauma patients with a focus on recent developments reported in the literature for emergency management.
Key words: Trauma, pregnancy, radiology, treatment, fetus

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Özet

Travması olan gebe hastanın doğru, yeterli ve zamanında yapılan bakımı hem anne, hem de fetüs için son derece önemlidir. Gebe travmasının tedavi yönetiminde iki hastanın durumu en iyi bir hale getirilmeli, fakat annenin sağlığına daha çok önem verilmelidir. Hızlı değerlendirme, tedavi ve transport anne ve bebeğin hayatını iyi bir şekilde sonuçlandırmak için çok önemlidir. Değerlendirmeler, gebelikte meydana gelen fizyolojik değişiklikler göz önünde bulundurularak yapılmalıdır. Travmada değerlendirme ve ressusitasyonun temel esasları anne için uygulanmalıdır. Fetüsün en iyi tedavisi anneye yapılan ciddi ressusitasyondur. Inferior vena kavaya bası yapmamak ve hipotansiyon oluşturmamak için tedavi sol lateral dekubit pozisyonda yapılmalıdır. Tedavi ile birlikte radyolojik tetkikler yapılmalıdır. Mümkünse invazif olmayan tanı yöntemleri kullanılmalıdır. Fetüsün durumunu değerlendirmek için acil serviste en kısa sürede yaşayan gestasyonlarda kardiyotokografik monitorizasyon başlatılmalıdır. Eğer fetal distersi? var veya fetüsün varlığı maternal stabiliteyi bozuyorsa acil sezaryen uygulanmalıdır.
Bu makale, travmalı gebe hastaların acil yönetimi için değerlendirme, tanı, tedavi ve eğilimlerindeki önemli özellikleri son literatür gelişmelerin ışığında yeniden gözden geçirmektedir.
Anahtar kelimeler: Travma, gebelik, radyoloji, tedavi, fetüs

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Introduction

Trauma is the most common cause of nonobstetric morbidity and mortality in pregnancy and complicates at least 6% to 7% of all pregnancies (1-3). The care of the pregnant trauma patient provides unique challenges and holds profound implications for both fetal and maternal outcomes. The incidence of trauma in pregnant patients is low, approximately 5% (4), but it is the leading cause of nonobstetric mortality, and the associated fetal morbidity and mortality increases with the severity of maternal injuries. The management of these patients is influenced by unique anatomic and physiologic changes, increased concern for deleterious radiation and medication exposures, and the need for multidisciplinary care. Anatomic and physiologic changes in pregnancy can mask or mimic injury, making diagnosis of trauma-related problems difficult. To the physician, these features represent a unique challenge because care must be provided for two patients. Many physicians are overwhelmed and intimidated in the management of these patients.

Epidemiology

The most common causes of trauma in pregnancy are motor vehicle accidents (49%), falls (25%), assaults (18%), guns (4%), and

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burns (1%) (1). When looking solely at injuries resulting in death, the 2 most common injuries are homicide and motor vehicle accidents, which account for 36% and 32%, respectively, with the remainder resulting from drug use, suicide, and other nonspecified causes (5). Identified risk factors for trauma in pregnancy are infrequent, but include younger age (6), drug use, alcohol use, and domestic violence (7). In particular, drug and alcohol use appear significant as risk factors for both trauma and for adverse outcome. Berenson and associates (8) found that women who were battered were more likely to use alcohol, drugs, and tobacco; and among women who had minor degrees of trauma in pregnancy, Holland and colleagues (9) reported a 21% incidence of preterm birth when the drug screen was positive. Sometimes, pregnancy itself can be a risk factor for trauma. Over recent years, attacks on pregnant women have gained prominence (10). These attacks are frequently targeted at the gravid abdomen, with intent to cause fetal injury (11).

According to the Centers for Disease Control and Prevention, trauma is the leading cause of death in women 35 years or younger. Maternal death rates from trauma may be noted as high as 10% to 11% (12, 13). In traumatic injuries the rate of fetus death is higher than death of the mother. With trauma, the majority of fetal mortality occurs due to placental abruption, direct fetal injury, unexplained fetal loss, maternal shock and disseminated intravascular coagulation (14). Largely because of the increase in size of the developing fetus and uterus, the risk of trauma to the mother and fetus increases as pregnancy progresses. The risk of maternal or fetal injury from trauma during the first, second and third trimester is 10% to 15% risk, 32% to 40% and 50% to 54% respectively (15).

Anatomic and physiologic changes in pregnancy

Typical prehospital and Advanced Trauma Life Support protocols must be modified in assessing the pregnant trauma patient because of alterations in anatomy and physiology. Additionally, the providers must consider the assessment and well being of the second patient-the fetus. These factors demand attention most immediately during the initial assessment and have implications in the effective resuscitation, diagnosis, and treatment.

The uterus first becomes an intra-abdominal organ at 12 weeks, and as it enlarges it displaces abdominal contents upwards, reaching the costal margin between 34 and 38 weeks. The diaphragm may be elevated as much as 4 cm, with accompanying displacement of associated thoracoabdominal organs, altering interpretation of physical examination and radiographic findings. In a supine patient, the enlarged uterus compresses the inferior vena cava, decreasing venous return and potentially causing supine hypotension syndrome.

There are numerous changes taking place in the cardiovascular system during pregnancy (Table 1). Blood pressure gradually declines from 10 weeks gestation until 28 weeks gestation. The systolic and diastolic pressures have decreased by 5 to 15 mm Hg at this point during the pregnancy. In the third trimester, blood pressure gradually begin increasing, returning to nearly pre-pregnancy readings. Central venous pressure decreases due to these effects (16). Progesterone and alpha-receptors cause cardiac output to increase to 30% to 50% above normal during the second trimester. In labor, there is an additional increase in cardiac output as each uterine contraction results in blood transfer from the uterus back into the circulation. The maternal cardiopulmonary system displays significant alterations. By the second trimester, a mild increase in resting heart rate and decrease in systolic blood pressure are accompanied by moderate hypocapnia caused by increased minute ventilation. Multiple factors affect maternal hemodynamics. Increases in maternal blood volume (by 50%) and relatively smaller increases in red blood cell volume (by 30%) create a physiologic anemia of pregnancy with expected hematocrit values between 30% and 35% in

Table 1. Hemodynamic changes during pregnancy

Physiology	Change during normal pregnancy	Normal range during pregnancy
Decreases		
Systolic blood pressure	Decreases by an average of 5–15 mm Hg	110–110 mm Hg
Diastolic blood pressure	Decreases by 5–15 mm Hg	50–70 mm Hg
Mean arterial pressure	Decreases by 10 mm Hg	80 mm Hg
Central venous pressure System vascular resistance	Slightly decreases or no change	2–7 mm Hg
Pulmonary vascular resistance Pulmonary capillary wedge pressure	Decreases by 10%–15%	75–95 beats/min
Oncotic pressure	Decreases by 10%–15%	1200–1500 dynes/sec/cm
Hematocrit	Decreases	6–9 mm Hg
	Decreases	16–19 mm Hg
	Decreases	32%–34%
Increases		
Heart rate	Increases by 10–15 beats/min	55–100 dynes/sec/cm
Cardiac output	Increases by 30%–50%	7 L/min at rest; 10 L/min
Cardiac index	increases	with stres
Blood volume	Increases by 30%–50%	4.0–4.5
Red blood cell volume	Increases by 30%	4500 mL
White blood cell count	May increase	-
Electrocardiogram	Flat or inverted T waves in leads III,	5000–15,000/mm
	V_1, and V_2; Q waves in leads III and aV_F	-

the final trimester (17). Nearly all coagulation factors increase throughout pregnancy (Table 2). Cardiac output remains elevated at third-trimester values for the first 2 postpartum days, and then it slowly declines to pre-pregnant values over the next 2 weeks. The net effects of these pregnancy-induced changes are an increase of procoagulants and a reduction in fibrinolysis, thus creating a hypercoagulable state.

The average estimated blood losses for a term vaginal delivery and cesarean section are approximately 500 mL and 1000 mL, respectively. This amount of hemorrhage typically results in no change in pulse, blood pressure, or other hemodynamic parameters. The mechanism by which the maternal systemic blood pressure is preserved is the result of vasoconstriction of the uteroplacental and splanchnic circulation. The first maternal signs of distress may not occur until hemorrhage of 1500 to 2000 mL has occurred. Hemodynamics of the mother are also affected by maternal position. During pregnancy, when the mother is placed in the supine position, the uterofetoplacental unit compresses the inferior vena cava. The result is decreased venous return and preload, and subsequently reduced cardiac output. This diminished cardiac output may result in significant hypotension, which often results in vaso-vagal-type symptoms.

The changes during pregnancy in the respiratory system are shown Table 2. The increased blood volume in pregnancy leads to capillary engorgement of the mucosa throughout the respiratory tract, causing swelling of the nasal and oral pharynx, larynx, and trachea. This is compounded by mucosal edema (16). The end results are difficulty in nasal breathing, epistaxis, and voice changes (18). These changes are adaptations to the increasing metabolic demands and oxygen delivery to the fetus. Oxygen consumption increases by 15% to 20% during pregnancy. Progesterone stimulates the medullary respiratory center, resulting in hyperventilation and respiratory alkalosis. The hyperventilation results in a decrease in the PCO_2 to a level of 27 to 32 mm Hg in the pregnant patient. The tidal volume and minute ventilation increase about 40% as the respiratory rate returns to baseline. Diaphragm elevation contributes to a 20% to 25% decrease in functional residual capacity. Fetal oxygenation remains constant provided the maternal PaO_2 remains above 60 mm Hg. Below this PaO_2 level, fetal oxygenation drops precipitously. When fetal oxygen saturation drops by half, the so-called "diving reflex" shunts fetal blood flow away from the liver and abdominal organs to the heart and brain, thereby exposing other organ systems to hypoxic injury (19).

The significant changes in cardiovascular, pulmonary and other organ systems during pregnancy cause some complications: desensitization of the peritoneum, gastric reflux, heartburn, vomiting, regurgitation and pulmonary aspiration (due to relaxing of smooth-muscle tone) (20, 21).

Anatomical and physiological changes in the abdomen and genitourinary system during pregnancy are shown in Table 3. Within the genitourinary system, the pelvic uterus becomes a lower abdominal organ by approximately 12 weeks gestation. Before 12 weeks, the small size and pelvic location of the uterus make it relatively resistant to injury (22). After the pregnant uterus becomes abdominal, the location predisposes it to injury from blunt or penetrating

Table 2. Anatomical-physiological and coagulation changes in the respiratory system during pregnancy

Changes	Change during normal pregnancy
Physiology or system	
Minute ventilation	Increases 40%
Tidal volume	Increases 40% (normal: 600 mL)
Minute ventilation	Increases 40% (normal: 10.5 L/min)
2,3-Diphosphoglycerate	Increases
Thoracic anteroposterior diameter	Increases
Partial pressure of oxygen	Increases (normal range: 100–108 mm Hg)
Oxygen consumption	Increases 15%–20% at rest
Risk of aspiration	Increases
Upper airway	Increased edema; capillary engorgement
Diaphragm	Displaced 4 cm cephalad
Respiratory rate	Slightly increases in the first trimester
Partial pressure of carbon dioxide	Decreases (normal range: 27–32 mm Hg)
Functional residual capacity	Decreases 20%–25%
Coagulation factor	
Fibrinogen	Increases (normal range 300–600 mg/dL; 3.0–6.0 g/L)
Factors I, II, V, VII, X, XII	Increases
Plasminogen activator inhibitor-1,-2	Increases (fibrinolytic activity may not be affected)
Protein C	Minimally increases
Prothrombin time	Decreases by 20%
Partial thromboplastin time	Decreases by 20%
Protein S	Decreases

abdominal trauma. Perhaps more importantly, uteropelvic blood flow increases markedly during pregnancy. By the end of pregnancy, this dramatic increase in pelvic blood flow increases the likelihood of appreciable hemorrhage in the event of uterine injury or pelvic trauma (13). Maternal death takes place in 10% of cases of traumatic uterine rupture,but the majority of fetal deaths occur with uterine rupture (19). In pregnant trauma victims uterine rupture is relatively uncommon (1%), and is generally associated with severe direct abdominal impact (23). In pregnancy, the bladder is displaced anteriorly and superiorly by the uterus, effectively becoming an intraabdominal organ and more susceptible to injury; and in the second and third trimester the ureters dilate (24).

Trauma pathophysiology and management in pregnancy

The mechanisms of injury and death are composed of multiple categories, including blunt and penetrating trauma, burns, electrocution, falls, and assaults. Many attempts have been made to identify factors that predict outcomes from maternal trauma, but few have been identified. Hypotension seems intuitive and seems predictive in some studies, but other studies have not validated these data (25, 26). It appears that initial maternal acidosis may be a useful indicator (25, 27), while initial pulse, white blood cell count, hemoglobin, oxygen saturation, and other physiologic or laboratory values are not useful (28-30). Penetrating injuries, burns, and electric shock, which are less common than blunt traumatic injury, may involve other pathophysiological mechanisms.

Prehospital considerations

In the prehospital setting, information regarding the status of the pregnancy and the clinical condition of the patient should be obtained. In general, most pregnant patients following major trauma should be transported to a Level 1 trauma center with obstetric facilities, particularly if there is hemodynamic compromise, tachycardia (heart rate >110 beats/min), chest or abdominal pain, loss of consciousness, or a third-trimester gestation (31). Appropriate spinal precautions should be observed, and a left lateral tilt position or manual displacement of the uterus may be used to avoid the supine hypotension syndrome. Care must be undertaken during the initial assessment because, as previously stated, vital signs and patient symptoms may not reflect the underlying injuries to the patient and fetus. General standard guidelines for trauma patients apply to the pregnant patient with some modification. Extrication should be performed in normal fashion with spinal immobilization being employed for most patients, especially those with blunt force trauma. In late third-trimester patients, a supine position may be intolerable because of the associated respiratory distress, and the prehospital team may use up to 30° of reverse Trendelenberg positioning as allowed by hemodynamic parameters (32). The use of towels or blankets placed under the backboard is quick, easy, and effective. Supplemental oxygen by nasal cannula or facemask should be given as soon as possible and considered routine. Two large-bore intravenous catheters should be placed and 1 to 2 L of resuscitative fluids initiated. The bolus of fluid may allow for continued perfusion of the uterine placental unit and prevent mild hypovolemia not noted in the vital signs. Gestational age must be reported. It is important to direct the transport to a proper hospital that can care for both the mother and a premature neonate if delivery is necessary.

Appropriate emergency department management can proceed only if the patient is identified as pregnant. Emergency medical service personnel, family or friends, physical examination, and serum or urine pregnancy testing may provide this information, but not without the potential for delay or misinformation. In 2002 Bochicchio and colleagues (33) recommended that all female trauma patients of reproductive age receive a Focused Assessment with Sonography in Trauma with the secondary intent to screen for pregnancy. On retrospective review, these ultrasound examinations revealed a small number of newly diagnosed pregnancies with subsequent modification to the diagnostic evaluation of these patients. Once pregnancy is identified, the evaluation of a pregnant trauma patient should be multidisciplinary, including a combination of emergency physicians, trauma surgeons, and obstetricians.

Clinicians should perform all necessary tests and procedures on the pregnant woman that are indicated, including radiologic imaging, intubation, central venous access, ultrasonographic evaluations, and even diagnostic peritoneal lavage. The patient may have experienced a significant loss of blood, but arterial pressure often remains stable due to the increase in blood volume during pregnancy and the shunting of blood flow away from the uterus. For this reason, fluid management is important. Waiting for maternal signs of hypotension will result in fetal compromise and distress. Fetal heart monitoring is useful to guide the adequacy of fluid resuscitation. Oxygenation by pulse oximetry must be observed; because hypoxia results in fetal distress and maternal oxygen reserve is significantly diminished, early endotracheal intubation may be considered. During the first

Table 3. Anatomical physiological changes in the abdomen and genitourinary system during pregnancy

Physiology or system	Change during normal pregnancy
Intraabdominal organs	Compartmentalization and cephalad displacement
Gastrointestinal tract	Decreased gastric emptying; decreased motility; increased risk of aspiration
Peritoneum	Small amounts of intraperitoneal fluid normally present; desensitized to stretching
Musculoskeletal system	Widened symphysis pubis and sacroiliac joints
Kidneys	Mild hydronephrosis (right > left)
Serum creatinine	Decreases (normal 0.6–0.7 mg/dL (50–60 µmol/L))
Serum urea nitrogen	Decreases (normal 3–3.5 mg/dL (1.1–1.2 mmol/L))
Bicarbonate	Decreases (normal 19–25 mEq/L
Renal blood flow	Increases by 60%
Glomerular filtration rate	Increases by 60%

and early second trimester, the woman may be tachypneic, but later in pregnancy other causes of respiratory compromise must be considered. If a chest tube thoracostomy is required, it needs to be placed one or two intercostal spaces higher than usual to avoid diaphragmatic injury. If rapid sequence intubation is required, lower dosages of succinylcholine should be used (34, 35).

Initial evaluation of the pregnant trauma patient

The primary survey is performed according to standard Advanced Trauma Life Support protocols, but special consideration must be paid to the cardiopulmonary alterations described earlier. Rapid-sequence induction is accepted as safe and is the preferred method for intubation. Appropriate techniques, such as Sellick's maneuver and adequate preoxygenation, are necessary to avoid complications, because pregnant patients are prone to aspiration and desaturation. Disturbances of respiration (eg, pneumothorax) may be more challenging to detect and may be associated with an accelerated decompensation because of alterations in respiratory mechanics. If tube thoracostomy is performed, a higher intercostal space should be used to avoid the elevated diaphragm. When evaluating the patient's circulatory status, the physiologic changes present in later pregnancy must be taken into account. The 50% increase in maternal blood volume and increased cardiac output may mask significant blood loss; fetal distress may be the earliest indicator of impending hemodynamic instability. Resuscitation with crystalloid should be initiated as appropriate, and, if needed before the availability of type-specific blood, O negative packed red blood cells should be used. Because of the susceptibility of the uterine blood supply, the use of vasopressors should be avoided.

After the primary survey is completed, a secondary survey should be performed with several important modifications. As early as possible in the resuscitation, fetal monitoring should be initiated for all viable gestations (>23 weeks) and continued for at least 4 to 6 hours (36). The decision to cease fetal monitoring should be made by the consulting obstetrician and should take into account documented uterine contractions, fetal well-being, and any plans for operative intervention. A vaginal examination should be completed to assess the presence of blood or amniotic fluid and cervical effacement and dilation. Vaginal fluid may be examined for the presence of ferning and an elevated pH near 7, which would be consistent with traumatic rupture of membranes. Vaginal bleeding may be present, indicating the possibility of placental abruption, uterine rupture, pelvic fracture with vaginal injury, or other injuries.

The standard Focused Abdominal Sonography for Trauma (FAST) examination should be performed during the secondary survey, providing a screening examination for intraperitoneal hemorrhage with sensitivities of 80% to 83% and specificities of 98% to 100% for intraperitoneal fluid (37, 38). With the advent of bedside ultrasound and rapid CT scans, diagnostic peritoneal lavage (DPL) has largely fallen out of routine use in the evaluation of trauma patients. The limited data on DPL in pregnancy report that it is accurate in pregnant patients and can be performed safely with no increases in fetal loss (39). If performed during pregnancy, a DPL should be done by the supraumbilical approach using an open technique.

A rapid but thorough secondary survey must include evaluation of the pregnancy. Great care and precision are needed in performing the abdominal examination because the normal physiologic stretching of the abdominal cavity may mask signs of significant peritoneal injury. Findings consistent with injuries to the liver or spleen include upper abdominal pain, referred shoulder pain, sudden onset of pain, and elevated liver transaminases. The uterus should be palpated carefully because tenderness and contractions may be overlooked. The top of the fundus should be marked to evaluate the possibility of concealed abruption as noted by an increasing fundal height. A sterile speculum examination is vital in the evaluation of the pregnant trauma patient. Fluid within the vaginal vault may be difficult to differentiate, but the use of nitrazine paper for a blue color change and the presence of ferning on microscopic examination aids in distinguishing alkaline amniotic fluid from urine. Vaginal bleeding may be present, indicating the possibility of placental abruption, uterine rupture, pelvic fracture with vaginal injury, or other injuries. The cervix should be visually inspected for evidence of dilation and effacement.

Cardiotocographic monitoring needs to be initiated in the emergency department as soon as possible, preferably on arrival after the secondary survey and FAST scan, because uterine contractions or irritability may subside with time. Monitoring times should be increased in those with contractions, abdominal pain, or significant maternal injury. Fetal ultrasound evaluation should include position of the fetus and heart rate, gestational age assessment, biophysical profile, fetal middle cerebral artery Doppler peak velocity for anemia, and evaluation of placenta for abruption. Unfortunately, ultrasound has a low sensitivity for detecting placental abruption (50%) (40). However, the positive predictive value is high. Ultrasound findings suggestive of placental abruption are (a) retroplacental hematoma (hyperechoic, isoechoic, and hypoechoic), (b) preplacental hematoma (gelatin-like appearance-shimmering effect-of the chorionic plate with fetal movement), (c) increased placental thickness and echogenicity, (d) subchorionic collection, and (e) marginal collection. In cases of penetrating trauma, it is important to evaluate the placenta as it relates to the site of injury. Visualization of streaming indicates placental vessel injury probably needing immediate delivery (34, 35).

Diagnostic evaluation

Many trauma centers evaluate patients with a standardized laboratory panel. Alterations in pregnancy that should be considered in interpreting laboratory results include a physiologic anemia, slight elevation of the white blood cell count, mildly decreased serum bicarbonate, and increased fibrinogen. Arterial blood gas analysis may reveal a slightly elevated pH and mild hyperventilation with pCO_2s near 30 mm Hg. Kleihauer-Betke (KB) testing identifies fetal red blood cells within a maternal blood sample, indicating fetomaternal hemorrhage of at least 5 mL using current methods, although the development of flow cytometry techniques may lower this threshold (41). The Rh-positive fetus possesses this antigen after 6 weeks' gestation, and transplacental hemorrhage of as little as 0.0001 mL of fetal blood can cause maternal sensitization. Consequently, the American College of Emergency Physicians recommends administration of immune globulin after even minor trauma (42). Similarly, the American College of Obstetrics and Gynecology recommends administering Rh immune globulin to all Rh-negative trauma patients who have a positive KB test (43). Further dosing to account for larger transplacental hemorrhage may be administered according to the dosing schedule of 300 µg of immune globulin per 30 cm^3 of estimated fetomaternal hemorrhage.

In 2004, Muench and colleagues (29) recommended routine KB testing in all cases of maternal trauma, regardless of maternal Rh status. In a retrospective review of 71 trauma patients, they report a

positive KB test holding a sensitivity of 100% in the prediction of uterine contractions and labor with a specificity of 96% and 54% for the prediction of contractions and preterm labor, respectively. Dhanraj and Lambers (44) however, comparing low-risk third-trimester volunteers with pregnant trauma historical controls, revealed no significant difference in the incidence of a positive KB test. The authors concluded that an isolated positive result therefore is not indicative of pathologic transplacental hemorrhage. Although this retrospective review has obvious limitations, it questions the potential utility of the negative predictive value of the KB test.

Diagnostic imaging in pregnancy

As mentioned previously, ultrasound is an ideal tool for imaging the pregnant trauma patient, because it provides valuable information about both the fetus and mother and has no associated radiation exposure. Often, however, additional diagnostic imaging is required. In general, clinically necessary imaging studies should not be deferred because of concern about radiation, and the uterus should be shielded as much as feasible given the intended study (45). The cumulative radiation dose associated with an increased risk of fetal malformation is 5 to 10 rads, significantly higher than many studies commonly used in trauma patients (46). A pelvic CT alone (with mandated absence of shielding) will administer between 3 to 9 rads to the fetus and should be be undertaken only in critical patients, as the clinical situation requires (45, 47). Although the literature suggests radiographic studies should not be deferred in the pregnant trauma patient, the increased use of CT in blunt trauma patient results in radiation doses that often exceed previously described thresholds (48). Clinicians are encouraged to consider these factors in choosing appropriate imaging studies. The fetus is most at risk for central nervous system effects from 8 to 15 weeks and the threshold appears to be at least 20 to 40 rad or 200 to 400 mGy. The American College of Obstetricians and Gynecologists (ACOG) has published recommendations for diagnostic imaging during pregnancy (49). Radiation dosages by study are listed in Table 4.

Table 4. Radiation exposure to an unshielded uterus/fetus

Imaging study	Uterine radiation dose in rads	Uterine radiation dose in milligray units (mGy)
Plain film studies		
Abdomen (AP)	0.133-0.92	1.33-9.2
Abdomen (PA)	0.064-0.3	0.64-3
Cervical spine	Undetectable	Undetectable
Chest (AP)	0.0003-0.0043	0.003-0.043
Chest (PA)	<0.001	<0.01
Femur (AP)	0.0016-0.012	0.016-0.12
Hip (AP)	0.01-0.21	0.1-2.1
Pelvis (AP)	0.142-2.2	1.42-22
Full spine (AP)	0.154-0.527	1.54-5.27
Lumbar spine (AP)	0.031-4.0	0.31-40
Thoracic spine (AP)	<0.001	<0.01
Computed tomography		
Upper abdomen	3.0-3.5	30-35
Entire abdomen	2.8-4.6	28-46
Head	<0.05	<0.5
Pelvis	1.94-5.0	19.4-50
Thorax	0.01-0.59	0.1-5.9

Shielding reduces exposure by 30%
Abbreviations: AP, anteroposterior; PA, posteroanterior

Injury severity scores and outcome in pregnant trauma patients

Much literature has been devoted to the description of factors associated with adverse maternal and fetal outcomes in trauma (13, 15, 31, 50-53). As described previously, trauma is one of the leading causes of maternal death and accounts for at least 5% of fetal deaths (13). Shah and colleagues (25) reported a mortality rate of 3.5% in a retrospective case-control analysis of 114 patients, which did not differ significantly from controls.

Several factors have been investigated to identify predictors of fetal injury and loss. It is well documented that the maternal Injury Severity Score (ISS) correlates well with adverse fetal outcomes (15, 26, 31, 28, and 29). Rogers and colleagues (27) reported a 50% fetal mortality rate with an ISS greater than 25. The assessment of a Revised Trauma Score in the initial resuscitation has been investigated as a potential marker of clinical course. A small retrospective analysis failed to identify a predictive value in assigning a Revised Trauma Score when examining for untoward outcomes or the need for prolonged monitoring (51). DIC was identified with equal incidence in patients with and without evidence of placental abruption, but was present only in the group with associated fetal mortality. Laboratory values consistent with DIC were found in 61.5% of these patients. The patients who have DIC should be considered for imminent delivery of a fetus of viable gestational age. Additional criteria that have been associated with fetal mortality include decreased Glasgow Coma Scale, maternal acidosis, decreased serum bicarbonate, maternal hypoxia, and a single documented fetal heart rate below 110 beats per minute, maternal malperfusion and hypoxia, direct uteroplacental injury, and severe maternal head injury (26, 28, 39).

Perimortem cesarean section

In cases of maternal cardiac arrest with potential fetal viability, perimortem cesarean section should be performed when resuscitative measures have failed. The best outcomes occur if the infant is delivered within 5 minutes of maternal cardiac arrest. This means the decision to operate must be made and surgery begun by 4 minutes into the arrest (54, 55). The latest reported survival was of an infant delivered 22 minutes after documented maternal cardiac arrest (56). Several factors must be considered when deciding whether to undertake perimortem cesarean section (57, 58). These include estimated gestational age (EGA) of the fetus and the resources of the hospital. The ability to salvage a fetus under ideal circumstances (availability of all skilled personnel and a controlled setting) may range from 23 to 28 weeks EGA. If the fetus is known to be 23 weeks EGA and the institution's nursery has never had a newborn of this EGA survive, perimortem cesarean section is probably not indicated for the sake of the fetus, but may improve maternal circulation by increasing cardiac return. Before 23 weeks gestational age, delivery of the fetus may not improve maternal venous return. Therefore aggressive maternal resuscitation is the only indicated intervention.

Injuries unique to the pregnant trauma patient

Blunt trauma

Blunt trauma during pregnancy may be the result of motor vehicle accidents, accidental falls, and violence. Different mechanisms of maternal injury occur in pregnant women with blunt abdominal trauma compared with injuries to their nonpregnant counterparts (25). Up to 25% of pregnant women with severe blunt trauma manifest hemodynamically significant hepatic or splenic injuries (59). Conversely, bowel injury is less frequent (60). Direct fetal injuries and fractures complicate less than 1% of cases of severe blunt abdominal trauma in pregnant women. The reasons for the low fetal injury rate are the protective nature of the maternal soft tissues, uterus, and amniotic fluid, the mandatory use of seat belts and shoulder restraints, and the presence of airbags as standard equipment in automobiles.

Penetrating trauma

Penetrating trauma in pregnancy is usually the result of gunshot or knife wounds. Other causes are much less frequent. The maternal death rate from gunshot wounds to the abdomen occurs in 3.9% compared with 12.5% of nonpregnant victims. The death rate from abdominal stab wounds is also lower for pregnant women compared to nonpregnant victims. The reduction in mortality stems from the anatomical changes induced by pregnancy. Visceral organs are displaced superiorly by the uterus, which results in the so-called "protective effects" of the uterus. Thereby visceral injuries are less common during pregnancy as well (33). However, when penetrating trauma involves the upper abdomen, a pregnant woman is more likely to suffer a visceral injury than if she were not pregnant. In these cases, the small bowel is more frequently injured, especially during the third trimester. Fetal injuries complicate 66% of gunshot injuries to the uterus (61). Fetal mortality ranges from 40% to 70% in cases of penetrating trauma and generally results from either premature delivery or direct fetal injury by the missile (61).

For the pregnant patient with penetrating trauma, management has become more controversial. Management options include immediate surgical exploration, diagnostic peritoneal lavage, laparoscopy, contrast-enhanced CT scanning, local wound exploration, and observation. Penetrating trauma to the upper abdomen is associated with an increased risk of maternal bowel injury and operative management is indicated (62). Pregnant patients with anterior abdominal stab wounds below the level of the uterine fundus are the best candidates for conservative management (62. Delivery of the fetus is rarely necessary unless there is direct perforating injury to the uterus or fetal death. In cases of uterine injury, care should be individualized to reflect the type of injuries present, the gestational age of the fetus, and the maternal and fetal prognosis if undelivered. Delivery of the fetus by cesarean section may be required if the gravid uterus prevents surgical exposure for repair of maternal injuries or in the presence of non-reassuring fetal status. In cases of fetal death, it is often possible and preferrable to attempt vaginal delivery by induction of labor.

Placental abruption

Placental abruption can occur even after minor abdominal trauma. It is the second most common cause of fetal mortality in this patient population (63); the incidence ranges between 1% and 60% (31). In minor trauma the rate of placental abruption is between 1% and 5% with significant mechanisms associated with rates of 20% to 60% (26, 31, 64). Placental abruption results from the placenta shearing away from the uterus with bleeding into this space and clot formation. The elasticity of the uterus, matched against the relative stiffness of the placenta, creates a vulnerable interface. A placental abruption can result in the patient experiencing abdominal pain, cramping, and vaginal bleeding. The clinician may detect uterine tenderness on physical examination. Unfortunately, the absence of these features does not exclude the diagnosis of placental abruption reliably.

Several diagnostic modalities may be used in the evaluation of placental abruption. Ultrasound may detect a placental abruption, has the benefit of the absence of ionizing radiation, and provides additional information about fetal well-being. Its sensitivity for placental abruption, however, is poor-around 50%-so a negative ultrasound does not rule out a placental abruption (19, 64). Use of the KB test as an indicator of the fetomaternal hemorrhage likely to accompany abruption is not of great clinical utility because of its low specificity, it is not recommended for this application by the American College of Obstetrics and Gynecology (43). Continuous fetal monitoring is the preferred test and should be initiated as early in the evaluation as possible. In the absence of symptoms consistent with placental abruption, an observation period of 4 to 6 hours is adequate (20, 50). Because of the potential for delayed manifestation (48 hours) of significant placental abruption, the Eastern Association for the Surgery of Trauma recommends continuation of fetal monitoring in the presence of uterine contractions, a non-reassuring fetal heart rate pattern, vaginal bleeding, significant uterine tenderness or irritability, or serious maternal injury (36). This recommendation applies to even minor trauma, because these patients are particularly prone to delayed recognition of placental abruption.

Uterine rupture

Uterine rupture is a rare consequence of maternal trauma, one that carries a grave outcome for the fetus. This diagnosis is present in less than 1% of blunt trauma and is found typically in patients who have had a previous cesarean section. Associated fetal mortality is nearly universal, with an associated 10% maternal mortality rate (20). Presenting features may include uterine tenderness and variable shape, hemodynamic instability, and the ability to palpate fetal parts on abdominal examination. In patients without a previous cesarean section, the uterus is more likely to rupture posteriorly, making detection of these physical examination findings more difficult (65).

Pelvic fracture

As expected from proximity alone, injuries to the bony pelvis are complicated to manage in pregnancy. Leggon and colleagues (66) described maternal and fetal mortality rates of 9% and 35%, respectively, in a retrospective review of 101 pelvic and acetabular fractures sustained during pregnancy. The major causes of fetal deaths were direct injury to the uterus, placenta, or fetus (52%) and maternal hemorrhage (36%). Fatal insults to the fetus were identified in all three trimesters, with no significant difference in the distribution of fetal mortality by gestational age. In subanalysis of this population according to injury severity, a fetal mortality rate of 10% was discovered in patients who had injuries of minor severity. These results are significantly higher than the generally accepted fetal mortality rates of 1% in this subset of pregnant trauma patients (31). Although the

research methodology has inherent limitations, this finding suggests that pelvic fractures may be an independent predictor of adverse fetal outcome.

The management of pelvic fractures in pregnant trauma patients has several critical modifications. Because of the increased risk of fetal morbidity and mortality, a thorough evaluation of the uterus and of fetal well-being must be undertaken. Recent reports, however, suggest that both percutaneous and open fixation may be performed with good fetal and maternal outcomes (67, 68). In addition to stabilization of unstable pelvic fractures, current management of hemodynamically unstable polytrauma victims often includes the use of angiography to coil or embolize bleeding pelvic or retroperitoneal vessels. The feasibility of this procedure in pregnant patients is not established.

In a large retrospective analysis of 3992 hospitalized pregnant patients who had fractures of any type, El Kady and colleagues (1) found lower extremity fractures were the most common, but pelvic fractures were associated with the highest risk of placental abruption and maternal and fetal death. Women who had pelvic fractures and who were discharged without delivering carried an increased risk of fetal, neonatal, and infant death, mostly attributed to abruption and low birth weight.

Electric shock

The incidence of fetal injury after electric injury to the mother is not known, but injuries appear to be rare during pregnancy. In general, the type and extent of an electrical injury depends on the intensity (amperage) of the electric current and resistance of the conducting material. The least resistance is found in amniotic fluid, nerves, blood, mucous membranes, and muscles; the highest resistance is found in bones, fat, and tendons. Skin has intermediate resistance.

For most pregnant women, electrical shock from low-voltage current, such as that used in North America (110V), results in no or minimal adverse effects on the mother. When electrical current traverses through the uterus, there is a high incidence of fetal death even when the woman has no adverse symptoms after the event. In these cases, fetal death may be immediate or might not become apparent until several hours after injury (69). Other fetal complications, including growth restriction, abruption, and abortion, have been reported following electrical shock (70, 71). Maternal ECG and the monitoring of fetal heart rate and uterine activity are recommended for 24 hours if the injury involved loss of consciousness, abnormal maternal ECG results, or known maternal cardiovascular illness. If a fall resulted from the electrical shock, then fetal and uterine monitoring is indicated for 2 to 4 hours, which is the same as for patients with blunt trauma. The fetus should have an ultrasound evaluation 2 weeks after the incident for assessment of fetal well-being.

Spinal cord injuries

The pregnant patient with acute spinal injury is treated the same as the nonpregnant patient and should receive intravenous methylprednisolone within 8 hours of the injury and continued for 24 hours. The management of a spinal cord injury in pregnancy depends upon the site, extent, and duration of the lesion. This is associated with significant improvement in motor and sensory function 6 months after the injury (72). It is also important to avoid maternal hypotension so as to maintain uterine blood flow and reduce the risk of secondary ischemic damage in the evolving lesion of the cord.

Domestic violence

Domestic violence is common during pregnancy and affects up to 20% of all pregnancies (73). It may be the leading cause of trauma in pregnancy. A pregnant woman is more likely to suffer domestic abuse than preeclampsia. Therefore, for physicians, diagnosing domestic abuse may be more crucial than diagnosing a placental abruption. Domestic violence may increase during pregnancy and lead to increased emergency room evaluations and antepartum and postpartum admissions (74). The abuser tends to focus the attack on the abdomen, breast, and genitals. The effects of domestic abuse on the fetus typically depend on the severity of placental injury. These effects range from preterm delivery, preterm labor, growth restriction, and low birth-weight as the severity of placental injury decreases. The first step in treating domestic abuse is identification. (73). The most effective strategies for identifying domestic violence are screening questionnaires followed by in-person interviews by highly trained individuals (75). A heightened index of suspicion and a concise screening tool may afford the emergency physician the unique opportunity to identify, intervene, and prevent recurrence of domestic violence. If domestic violence is suspected, consultation with social services should not be delayed.

Injury prevention

Given the dramatic impact on fetal well-being and the prevalence of traumatic injuries in women of childbearing age, there are great potential benefits in the prevention of traumatic injuries in pregnant patients. Although there is discrepancy in the literature regarding the etiology, most authors identify motor vehicle collisions as the primary source of traumatic injuries. Even though the use of seatbelts is recommended, many pregnant patients do not use them. Approximately one third of pregnant patients do not use safety restraints properly, and a minority of women report physician counseling on this topic (76, 77). Previous literature suggests as few as 46% of pregnant women involved in motor vehicle collisions were properly restrained, with as few as half of all pregnant women reporting routine proper use of restraints (26, 78, 79). Therefore, great emphasis has been placed on appropriate positioning of the lap and shoulder belts. Recently, the role of airbag deployment in obstetric complications has been investigated in case reports and series. Fusco and colleagues (80) reported the first case of uterine rupture associated with airbag deployment. Subsequently, a retrospective review by Metz and Abbott (81) of 30 cases involving airbag deployment failed to demonstrate a high rate of abruption or fetal compromise. Although preliminary experimental data suggest airbags may impart a dangerous force to the uterus with improper use, the risk of airbags in late-trimester patients remains to be defined (82).

The prevalence of violence in pregnancy is estimated to be 10% to 20%, with some series identifying up to 31.5% of traumatic injuries as attributable to interpersonal violence (83). Most of these assaults (70%-85%) are attributable to boyfriends or spouses. The frequency and/or nature of abuse may escalate during pregnancy and is associated with late entry into prenatal care, prematurity and low birth weight in addition to any immediate implications of the traumatic insult. The available structure of routine prenatal visits and the potential for increased use of emergency departments by this patient population may provide opportunities to detect patients subjected to domestic violence. Several methods for detection have been described, and guidelines for screening are available from the American College of Obstetrics and Gynecology (84, 85).

Summary

Trauma is the leading nonobstetric cause of maternal mortality, with the majority of injuries occurring from motor vehicle accidents. The basic tenets of trauma evaluation and resuscitation should be applied in maternal trauma. It is important to understand the mechanism of injury, as well as the anatomical and physiological changes present in pregnancy. Failure to do so may have a significant impact on maternal hemodynamics and the fetus. Therefore aggressive resuscitation of the mother is the best management for the fetus. Care must be taken to keep the patient in the left lateral decubitus position to avoid compression of the inferior vena cava and resultant hypotension. Radiographic studies should not be avoided, but rather used with care. Noninvasive diagnostics, such as abdominal ultrasonography, should be used when available. Cardiotocographic monitoring of viable gestations (>20 weeks' gestation) should be initiated as soon as possible in the emergency department to evaluate fetal well-being, because fetal well-being is often the best indicator of maternal health. Seemingly minor injuries can result in placental abruption. Therefore monitoring is required for at least 2 to 4 hours after any trauma. KB testing should be considered in all cases of blunt trauma to determine the risk of preterm labor and placental injury. Rh-negative mothers should receive Rh-immune globulin administration to reduce the risk of Rh immunization. While routine cesarean section is not warranted, even in patients requiring laparotomy, urgent cesarean section should be considered if fetal distress is present, or if the presence of the fetus is contributing to maternal instability. For best fetal outcomes, perimortem cesarean section should be undertaken within 5 minutes of maternal circulatory arrest. Screening for domestic violence, particularly in patients with repeated injuries, should be undertaken and appropriate interventions made when identified. Finally, trauma centers and emergency departments should have protocols in place that address the unique situations for trauma occurring during pregnancy. These protocols should include inputs from all specialists involved in this multidisciplinary emergency.

Conflict of Interest

No conflict of interest is declared by the authors.

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