Trauma in pregnancy

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INTRODUCTION

Few emergencies are as complex and anxiety inducing as a major trauma case involving a pregnant woman, where the safety and well-being of both the gravid woman and her developing fetus must be assessed and safeguarded simultaneously. Alterations in both anatomy and physiology during pregnancy must be kept in mind even in the chaos of the trauma room. Input will be required from emergency medicine, surgery, and obstetrics, with involvement as needed from other specialties such as anesthesiology, radiology, pediatrics, and critical care medicine.

EPIDEMIOLOGY

In the United States, up to 8% of women will experience a traumatic injury during pregnancy,[1] though figures are not well sourced or supported. Fortunately, the great majority of these injuries are minor. However, trauma remains a leading cause of nonpregnancy-related maternal death, accounting for more than 25% of maternal deaths reported to the (voluntary) Pregnancy Mortality Surveillance System.[2] The maternal mortality rate from trauma during pregnancy was 1.4% in the US National Trauma Data Bank[3] and 5.1% in a national registry from the United Kingdom[4]; UK figures, however, show a much lower incidence of trauma during pregnancy than American data. Pregnancy does not make injury more lethal: In fact, in the National Trauma Data Bank, pregnant women had a 40% lower risk of death than age-matched nonpregnant women who sustained trauma,[5] though mortality rates in the UK were much the same between pregnant and nonpregnant women after trauma.[4]

Trauma may be blunt or penetrating. About 90% of abdominal trauma during pregnancy is due to blunt injury,[6] the major contributors being motor vehicle accidents (MVA), assault, and fall. Penetrating trauma is more dangerous to both mothers and fetuses: Maternal mortality rates in a large case series were 2% for blunt versus 7% for penetrating abdominal trauma, while fetal mortality was 10% versus 73%.[6] Because MVA contribute so greatly to trauma incidence in the US, attention has been paid to ways to reduce mortality, specifically with use of restraints and airbags. The National Automotive Sampling System/Crashworthiness Data System (NASS/CDS) database reports there are approximately 160,000 MVAs annually which involve pregnant women, resulting in an estimated 160 maternal deaths and an additional 600–2600 fetal losses[7] even when the mother survives. The NASS/CDS database showed that nearly 25% of pregnant crash victims were unrestrained. The degree of severity is shown by the fact that airbags deployed only 33% of the time, and 99% of injuries were deemed minor.[7]

Interpersonal violence accounts for 10%–12% of blunt trauma cases from US case series.[3,6,8] Of these, a disturbing 43% are related to domestic violence (DV) (Aboutanos et al. 2007) also known as intimate partner violence (IPV). The incidence of DV is almost certainly underreported. Assault during pregnancy triples the risk of preterm labor

and of stillbirth, quadruples the risk of abruption, and increases nearly fourfold the risk of maternal death.[9] In a series from a metropolitan trauma center in South Africa, more than half of pregnant women admitted after trauma had been subjected to deliberate assault.[10]

Falls contributed 14% of trauma admissions in a large database series from California[8] and 48% in a single-center case series limited to minor trauma.[11] A cross-sectional study of pregnant women in Nigeria found that 32% reported having fallen during pregnancy, with the highest number of falls occurring in the third trimester[12]; not all were taken to hospital. A linked data set from Washington State calculated 49 fall hospitalizations per 100,000 deliveries, of whom 79% were in the third trimester; most suffered no more than minor injuries[13] but the rate of adverse pregnancy outcomes nevertheless was increased. Postural stability worsens during pregnancy, and objective measures of fall risk are highest in the third trimester.[14]

Other causes of trauma include thermal injury. No reliable estimates of burn injury during pregnancy have been generated for North America, though El Kady, dividing number of burn admissions by total number of deliveries in California during the time period studied, calculated 0.06 burn admissions per 1000 deliveries.[8] Case series from the developing world (India, Iran), where burns are much more common, probably have limited applicability here, but do link the probability of maternal survival to the total body surface area burned.[15,16] Fetal survival depends on maternal survival and gestational age achieved.

Among pregnant women admitted to California hospitals following trauma, fractures, dislocation, or sprains were the most common injuries, affecting 36%; 6% sustained intracranial injuries, 6% internal injuries (chest, abdomen, pelvis), 2% nerve and spinal cord injuries, and 2% were admitted with burns.[8] Women who delivered during the admission for trauma had worse outcomes than a control group without injury: Odds ratios of 42 for uterine rupture, 9.2 for abruption, 7.8 for cesarean hysterectomy, and 69.5 for maternal death were reported. Women who had been hospitalized for injury but discharged undelivered had better outcomes than those delivered during the trauma hospitalization, but still worse than the control group who had had no trauma. Fetal outcomes were also worse among the group delivered during trauma hospitalization, if less dramatic: Odds ratio was 4.7 for fetal death, 3.1 neonatal death, and 2.1 for preterm delivery.[8] It is obvious, however, that severity of injury was related to the probability that delivery would occur during the admission for trauma, while women with less severe injuries could be discharged home undelivered.

ASSESSMENT AND MANAGEMENT OF THE ACUTELY INJURED GRAVIDA

Trauma survey

"The best initial treatment for the fetus is the provision of optimal resuscitation of the mother"—*ATLS*, 9th edition.[17]

The primary survey remains the foundation of trauma triage, regardless of pregnancy. Abiding by Advanced Trauma Life Support (ATLS®) guidelines for assessment and management of the injured patient has been shown to improve patient outcomes[17] and this remains true in the obstetric patient. As a rule, maternal resuscitation and stabilization directly improve fetal outcomes.

The primary survey in the obstetric patient closely follows nonpregnant guidelines with a few caveats we will discuss below.

PREHOSPITAL PHASE

Assuming the pregnancy is known to the patient herself, awareness and reporting of pregnancy by the prehospital triage team allows for mobilization of the obstetric team so they can be present and ready for arrival of the patient in the trauma bay. Knowledge of the approximate gestational age will also allow for fetal assessment as indicated during the secondary survey. Field triage recommendations from the CDC cite pregnancy (>20 weeks) as a reason for EMS to contact medical control and transport to a trauma center or to a hospital with specific resources, i.e., obstetrical services.[18] Hospitals may also use the presence of pregnancy as a criterion for trauma team activation and hospital admission,[19] though others decry the practice[20] as it represents overtriage: Pregnant patients are no more likely to have major injury, and routine trauma team activation in these cases is probably not cost effective.

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PRIMARY SURVEY

The underlying principles behind ATLS[17] remain valid in the obstetric patient.

Treat the greatest threat to life first.

- That is, in order of danger: Loss of airway is more emergent than loss of ability to breathe, which is more important than loss of blood volume, which is much more important than fetal "distress."

Lack of definitive diagnosis should not delay indicated treatment.

- Presence of a fetus should not distract the trauma team from initiating life-saving maneuvers.

Detailed history is not essential to evaluation of a patient with acute life-threatening injuries.

- Obstetric history and assessment can follow during the secondary survey, after initial resuscitation has been conducted. Obstetric history taking should not trump the primary survey.

The primary survey is generally performed by the emergency medicine or trauma team. The mnemonic ABCDE as prescribed by ATLS should be followed for the primary survey.

A—Airway (with cervical spine protection)
B—Breathing
C—Circulation: Identify and stop bleeding
D—Disability or neurologic status
E—Exposure (undress the patient) and Environment (prevent hypothermia)

Only after these have been addressed is attention turned to F—fetus.

Any woman of childbearing age should be assessed for pregnancy via clinical history, physical examination, urine, or serum testing. This evaluation can be performed concurrently with the primary survey, as long as it does not interfere, or await the secondary survey if pregnancy is not initially evident. Determination of gestational age is important during the secondary survey, as it may influence the nature of interventions required.

AIRWAY AND BREATHING

Pregnant patients exhibit an increase in oxygen consumption, an increase in tidal volume, and a decrease in functional residual capacity (FRC). Patients in the second trimester and beyond are usually hypocapnic ($PaCO_2$ = 30 mmHg) and therefore a "normal" $PaCO_2$ of 35–40 may be falsely reassuring as it may in fact reflect impending respiratory failure.[17] Early ventilatory support, including intubation if needed, is prudent to ensure adequate oxygenation.

Pregnancy increases risk for airway complications because of weight gain, airway mucosal edema, and delayed gastric emptying. Failed intubation is four to eight times more likely in the obstetric patient than the general population,[19,21] and even in current practice[22] a rate of 1:224 is seen. Failed intubation in a pregnant patient is associated with more extreme hypoxemia because of alterations in oxygen demand, minute ventilation, and FRC: In a case–control study of obstetric anesthesia cases, oxygen saturations as low as 40% were reached.[22] Availability of experienced anesthesia staff is vital to the safety of the obstetric patient.

Given the possibility of a full stomach in every trauma patient, definitive airway management often includes rapid sequence intubation (RSI) with cricoid pressure. This involves an agent for induction of anesthesia and another for muscle relaxation. Propofol and ketamine are commonly utilized in trauma cases; like all induction agents, they cross the placenta and therefore will depress fetal neurobehavior. If delivery occurs soon afterward, there is no opportunity for maternal metabolization and excretion, so neonatal depression may ensue and the pediatrician should be prepared to address it. Muscle relaxants, both depolarizing and nondepolarizing agents, *do not* cross the placenta.

Because of the higher minute ventilation and decreased FRC common to pregnancy, there is more potential for desaturation: The threshold for giving supplemental oxygen should be low even if definitive airway management is not required.

Given the elevation of the diaphragm with the enlarged uterus, if a thoracostomy tube is required, it should be placed one to two intercostal spaces higher than the usually accessed fifth intercostal space to avoid intra-abdominal injury.[1,23]

CIRCULATION

Pregnant patients exhibit the physiologic differences seen in Table 35.1.

Given the increased plasma volume and cardiac output, a pregnant patient can hemorrhage 1200–1500 mL of blood before exhibiting signs and symptoms of hypovolemia. However, the resulting catecholamine release and vasoconstriction may reduce placental perfusion and produce fetal distress prior to signs of maternal distress. The therapy remains maternal stabilization, as pregnant patients do respond appropriately to volume resuscitation. It should be mentioned that a pregnant patient is expected to have a slightly elevated resting heart rate and relative hypotension, both signs that may falsely raise concern for hemorrhage. A good clinical sense and experience treating obstetric patients will come useful.

Transfusion of blood products is indicated as needed to maintain maternal physiologic needs. If cross-matched blood is not available or there is not enough time for cross-matching, O-negative blood should be transfused to avoid Rh sensitization in Rh-negative women. Maternal hematocrit does not correspond in any way with fetal hematocrit.

It is important to bear in mind the influence of the gravid uterus in compressing the inferior vena cava when a patient is in the supine position. The decrease in venous return and preload can lead to a 30% reduction in cardiac output and possibly dampen resuscitative efforts. Every effort should be made to either place the patient in a left lateral position or manually displace the uterus to the left side to relieve IVC compression. The venous congestion caused by uterine compression may also impede medication delivery via intravenous access below the diaphragm: Femoral access should be avoided. If the pneumatic antishock garment (PASG, also known as military or medical antishock trousers, MAST) is used, the abdominal section should not be inflated because of concern it may interfere with placental perfusion,[23] but this is a largely obsolete technology.

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DISABILITY

Altered sensorium in the pregnant patient mandates including eclampsia and the posteclamptic (post-ictal) state in the differential. Evidence of hypertension,

Table 35.1 Physiologic differences in pregnant patients.

Increased plasma volume	Up to 45%
Increased cardiac output	By 1–1.5 L/min ; 20% of cardiac output distributed to uterus and placenta in 3rd trimester
Decreased hematocrit	31%–35%
Elevated resting heart rate	By 10–15 beats/min
Decreased systolic and diastolic blood pressure	By 5–15 mmHg

hyperreflexia and proteinuria further support eclampsia, but in the setting of hemorrhage from trauma, hypertension may be absent.

Active seizures in a pregnant patient, absent head trauma, can be presumed to be eclampsia and managed by intravenous magnesium sulfate (6 g bolus + 2 g/hour) while obstetrical or neurological consultation is requested.

EXPOSURE

Evaluation should include a pelvic examination for vaginal bleeding as a source of hemorrhage. However, if vaginal bleeding is identified, digital examination should be deferred until placenta previa is excluded.

SECONDARY SURVEY

After completion of the primary survey, the establishment of resuscitative efforts as needed, and restoration of normal vital signs, the obstetrician has a role in the secondary survey:

- assessment of gestational age and viability
- evaluate specific obstetric emergencies such as uterine rupture or placental abruption
- check cervical dilation and rupture of membranes (screen for preterm labor)
- begin the process of fetal assessment

This is the time to obtain a history, whether from the patient herself or from family members or other sources. This is also the time to obtain needed imaging studies (Figure 35.1).

Blunt injury accounts for the majority of trauma in pregnancy (see Epidemiology). The mechanism of injury may be useful in directing evaluation toward commonly associated injury patterns: For example, thoracic injury after head-on motor vehicle collision, head injury or aortic trauma after auto-versus-pedestrian accidents, etc.[17] The presence of a space-occupying gravid uterus affects these patterns.

In the first trimester, the uterus remains in the bony pelvis, making direct fetal injury rare (<1%). In later gestation, while the fetus remains somewhat protected by the presence of multiple layers (amniotic fluid, uterine myometrium, and the maternal abdominal wall) the risk of direct fetal injury from blunt trauma does increase. The same layers serve to shield maternal viscera. At any gestational age, the trajectory of ballistic wounding (bullets, shrapnel) is unpredictable.

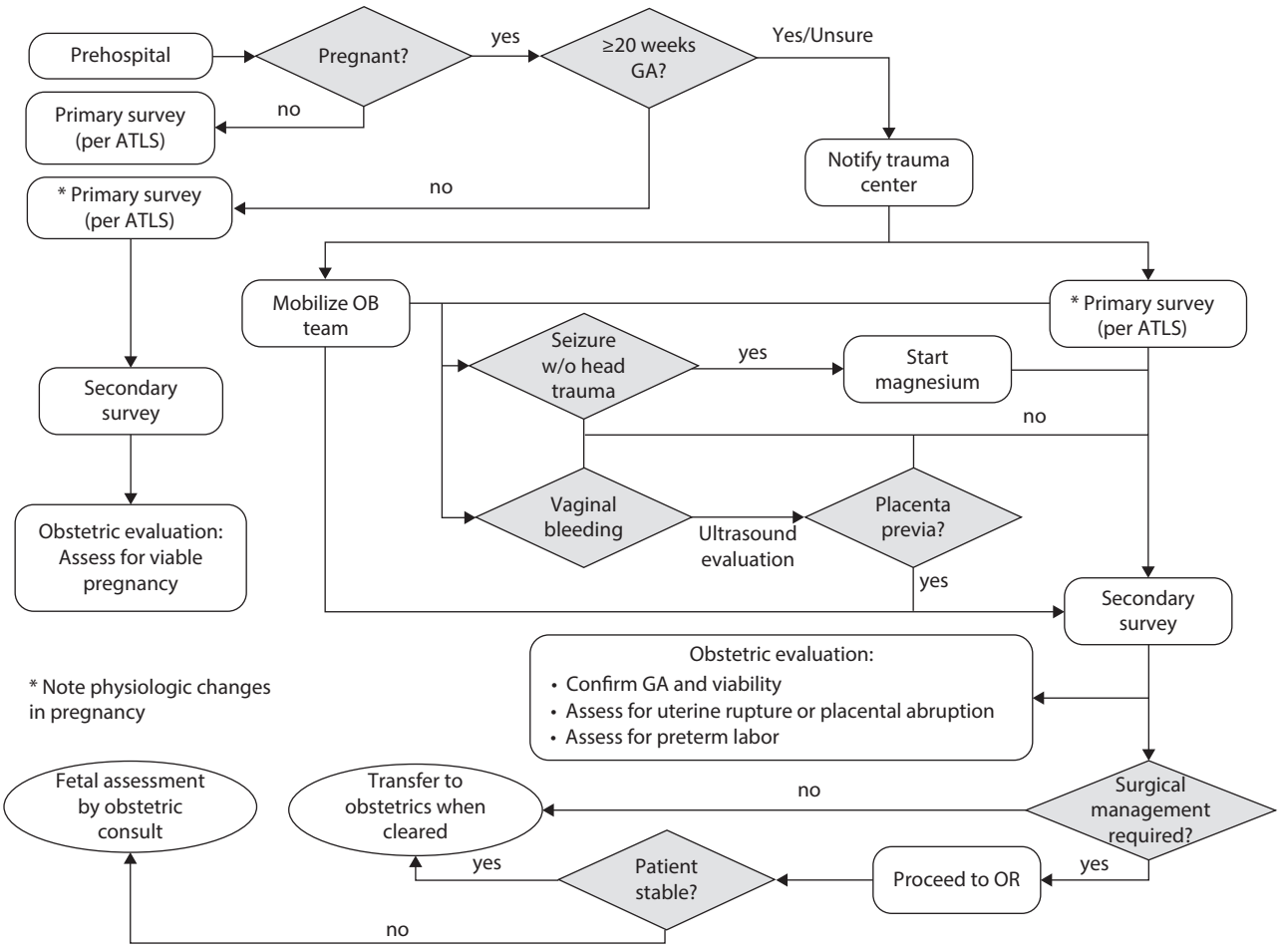

Figure 35.1 Mechanisms of injury—changes in anatomy.

Fetal injury is more commonly a result of indirect factors after blunt trauma, however: The uterus is deformable with high pressures, but as the placental attachment site is not, shear forces may result in placental abruption. Abruption has been reported to follow both major and minor degrees of maternal abdominal trauma. Though placental abruption is more likely at the time of admission for trauma, rates are also higher even among women who were discharged undelivered after trauma.[8]

Restraints (seat belts), properly worn, are protective to the pregnant patient (and therefore her fetus) involved in an MVA. Unrestrained pregnant women experience a higher risk of complications including premature delivery and fetal death. Proper placement involves a shoulder restraint above and a lap belt below the uterus. Airbags and their deployment have not been proven to increase fetal risks in pregnancy and, in fact, would be expected to save fetal lives by the simple expedient of saving maternal lives.

Penetrating injury is less common in pregnancy than blunt trauma but increases the likelihood of direct fetal injury. The uterus and its contents protect the patient's viscera, but the fetus generally does poorly.

As gestational age increases, the uterus displaces the bowel cephalad, so bowel injury becomes less likely with advancing gestation. The gravid uterus also displaces the bladder out of the bony pelvis, making it more susceptible to injury. Hematuria warrants prompt investigation. If maternal urine is contaminated with meconium or vernix, it is especially concerning for vesicouterine rupture.

The gravid uterus receives up to 600 mL/min of blood supply in the third trimester (20% of the cardiac output) and in the event of uterine rupture can be a major source of blood loss. It is possible for the uterus to distend enough to accommodate the entire circulating blood volume, thereby providing a large potential space for blood loss.

Pelvic fractures, which may result from blunt trauma, can be a source of significant retroperitoneal blood loss, especially because of the engorgement of pelvic vessels in pregnancy. A stable maternal pelvic fracture does not exclude vaginal delivery but consultation with an orthopedic surgeon would be indicated for safe patient positioning, since a standard lithotomy position may be imprudent under the circumstances.

EVALUATION OF FETO-MATERNAL HEMORRHAGE

The presence and degree of feto-maternal hemorrhage (FMH) has been studied as an indicator of the severity of obstetric trauma.[24] The inelastic placenta attached to the more elastic myometrium is prone to injury, and any disruption can result in fetal blood being spilled into the maternal circulation. FMH has been noted to occur in 10%–30% of traumas, with increasing incidence with advancing gestation. This is particularly important in Rh negative patients that have the potential for Rh alloimmunization. Even minor trauma has the potential for causing an Rh sensitization event in the mother, and all Rh-negative patients should receive anti-D immune globulin G within 72 hours of the event.[23]

While even 0.001 mL of fetal blood can result in alloimmunization, the routine dose of 300 μg Rh immune globulin will provide prophylaxis against 30 mL of fetal blood (15 mL of fetal RBC). If there is concern for larger FMH, the Kleihauer–Betke (KB) test can quantify the amount of fetal blood cells in maternal circulation so as to calculate the needed dose of Rh immune globulin.

Muench et al.[24] studied the utility of KB testing in all cases of maternal trauma regardless of Rh status and reported that a positive KB correlated with presence of contractions and progression to preterm labor. These authors have advocated routine KB testing in all trauma cases, but others recommend routine testing only in Rh-negative patients[23] since tocodynamometry is likely to be performed in all patients regardless.

COAGULOPATHY AND TRAUMA

Nonobstetric bleeding in a pregnant trauma patient should follow standard trauma protocols. Site-specific bleeding from a major injury can be life-threatening and should be stabilized emergently with either temporary (compression) or definitive (surgical or interventional) management. While anatomical bleeding can be corrected surgically, diffuse microvascular bleeding from a deranged coagulation system cannot, and may vitiate lifesaving interventions.

Recent literature from trauma and critical care sources shows that coagulopathy is present in one-third of bleeding trauma patients upon initial presentation to the hospital.[25] These patients require more transfusions and have longer stays in the intensive care unit (ICU), higher incidence of multiorgan dysfunction and a fourfold increase in mortality, compared with patients with a functional coagulation system. Especially pertinent in obstetrics is the role of placental abruption, overt or concealed, and its potential to trigger coagulopathy.

Post-traumatic coagulopathy has been mainly attributed to either widespread activation of the clotting cascade, leading to consumptive coagulopathy, or dilutional coagulopathy secondary to large-volume crystalloid resuscitation. While intravenous fluids can be lifesaving, large-volume infusions may worsen bleeding by increasing intravascular hydrostatic pressures and washing away clots that are being formed.[25,26] Strategies of hypotensive or hemostatic resuscitation are directed not at maintaining normal blood pressure but maintaining only the minimal cardiac output required to sustain organ function while preserving normal coagulation. This typically requires limiting crystalloids, accepting lower blood pressures, administering antifibrinolytic agents such as tranexamic acid, and transfusing plasma and platelets early, rather than red blood cells (RBC) only.[26] Operative control of bleeding is achieved quickly, even if this means damage control rather than definitive surgery. It must be pointed out that hypotensive resuscitation has not been studied in pregnancy, though it has been proposed as an adjunct to surgical control of postpartum hemorrhage.[27] Hypothermia and acidosis are known to hinder clotting

factor function and worsen coagulopathy: Thus, precautions must be taken to avoid them.

Although the degree of coagulopathy is related to severity of injury, hemodynamically stable patients may, rarely, present with clotting dysfunction. A distinct coagulopathy of trauma seems to be directly related to the degree of tissue hypoperfusion precipitated by the shock state. Acute coagulopathy of Trauma-Shock (ACoTS), characterized by systemic anticoagulation and hyperfibrinolysis, has not been specifically studied in pregnancy trauma and is beyond the scope of this chapter.

Pacheco et al., after a thorough review of current trauma literature, advocate changes in resuscitation protocols for obstetric hemorrhage,[28] which may be considered in case of severe trauma complicating pregnancy. They recommend hemostatic resuscitation that involves the following:

Limitation of aggressive crystalloid use early in resuscitation, and perhaps permissive hypotension; permissive hypotension has not been studied during pregnancy, however, and the fetoplacental effects are unknown.

Early administration of fresh frozen plasma (FFP) and platelets along with packed RBC, aiming for a ratio of 1:1:1 without waiting for coagulation laboratory tests.

Early use of recombinant factor VII (rFVIIa.)

Trauma literature now strongly advocates a 1:1:1 ratio of transfusing FFP and platelets with RBC to reduce the development of coagulopathy. Combat injury data has shown significant improvement in survival outcomes with higher plasma to packed RBC (PRBC) transfusion ratio,[29] as have subsequent trials in a civilian trauma population,[30] and a policy of high plasma-to-RBC ratios has subsequently been adopted into many massive hemorrhage protocols, including obstetric hemorrhage. However, as Pacheco et al. points out, trauma studies are significantly weakened by the possibility of survival bias: FFP takes time to thaw and thus the patient who receives it has already survived longer. The few studies attempting to address this bias have shown no benefit from higher plasma transfusion ratios. More prospective studies are needed to provide guidance, but at the time of this writing, early FFP and platelet transfusion is recommended.

In case of a planned (nonemergent) trip to the operating room, intraoperative cell salvage is a viable option for obstetric patients and can reduce the need for allogenic blood products. The theoretical concern for an amniotic fluid embolism caused by unfiltered amniotic fluid in salvaged blood has not been seen in clinical practice in over 400 obstetric patients.[1]

DIAGNOSTIC IMAGING MODALITIES AND SPECIAL CONSIDERATIONS DURING PREGNANCY

After maternal resuscitation and stabilization, focus is shifted to the diagnosis of nonobvious injuries and evaluation and management of the fetus. This constitutes the secondary survey.

Diagnostic imaging is often important to determine the extent of intra-abdominal or other internal injury and to confirm whether there is a need for nonobstetric laparotomy or other surgery.

Focused assessment with sonography in trauma (FAST) is typically used during the secondary survey to look for free intraperitoneal fluid. During this examination one visualizes the pericardium, the right upper quadrant, left upper quadrant and the suprapubic area in a search for free fluid.[17,23] In pregnant patients, FAST performs well: Sensitivity was 83% and specificity 98% in a group of 127 who had sustained blunt abdominal trauma.[31] It does depend to a certain extent on the sonographer's skill and the acoustic attenuation of the abdominal wall, being less satisfactory in obesity.

Bedside ultrasonography (US) can also be utilized to determine the approximate gestational age (GA) of the fetus and presence (or absence) of fetal cardiac activity. The location of the placenta, presence of a retroplacental clot, and position of the fetus can be determined, but sensitivity of ultrasound for placental abruption is inadequate. As an adjunct to the secondary survey, continuous electronic fetal heart rate monitoring may be appropriate, depending on gestational age, severity of maternal injury and potential for fetal decompensation. Presence of fetal well-being can also be utilized as an additional marker of maternal physiologic stability. Fetal concerns cannot, of course, be allowed to override maternal concerns.

Computed tomography (CT) scanning is a crucial element of trauma imaging. The concern for CT in a pregnant patient revolves around the radiation exposure to the developing fetus. The potential for harm from radiation exposure depends on the gestational age. Immediately after conception (<2 weeks), there may be blastocyst failure, with harm being an all-or-nothing event. Between 2 and 10 weeks the embryo or fetus is vulnerable to teratogenesis with the threshold thought to be from 50 to 150 mGy; after 10 weeks, the major concerns with high exposures would be fetal growth restriction or effects on brain development.[23]

Fetal exposure from background radiation ranges from 0.5 to 1.0 mGy in a normal pregnancy. A single CT of the chest has an estimated exposure of 0.2 mGy.[32] In contrast, a CT of the abdomen and pelvis with the fetus in direct view can approach 50 mGy but, unless repeated, usually still remains below the threshold. Techniques to reduce the fetal radiation dose may be employed if the radiologist deems they will not compromise image quality.

Reaching 50 mGy of exposure increases the overall lifetime cancer risk by 2% in the perinate and doubles the risk of fatal childhood cancer (new risk: 1 in 1000).[32]

NONOBSTETRIC SURGERY DURING PREGNANCY

Maternal injury during pregnancy may require surgical intervention. Craniotomy, thoracotomy, laparotomy, or surgery of the extremities may be required. Nonemergent procedures may be deferred for hours or, more rarely, even days in some cases, such as extremity fractures, in order to optimize presurgical and preanesthetic circumstances. In some cases, the surgical technique may be

altered by the fact of pregnancy, as when the orthopedist chooses an open plating technique for repair of long bone fracture rather than percutaneous plating or an intramedullary nail, so as to reduce total radiation exposure intraoperatively.[33]

If emergency laparotomy is indicated for trauma, the goals for surgery should be clearly elucidated. Gunshot wounds to the maternal abdomen will typically require exploration, but typically will be associated with fetal death. Penetrating abdominal trauma from stab wounds may injure the uterus and thereby injure the fetus, but if the uterus is large enough, will not usually have injured other maternal viscera. The enlarging uterus will have pushed bowel cephalad, however, so upper abdominal injuries may well be associated with bowel trauma.

In recent years, the concept of selective nonoperative management (SNOM) of abdominal trauma has come to the fore, first for blunt trauma and then for penetrating trauma.[34,35] Candidates for this type of management must be hemodynamically stable, have no evidence of peritonitis, and have no hollow viscus injury on CT scan; solid-organ injury does not rule out SNOM. This approach has been successful in reducing exploratory laparotomy among adult (nonpregnant) patients after abdominal trauma, though 15%–20% will fail SNOM and require laparotomy.[34] Evaluation of selective nonoperative management among pregnant patients after abdominal trauma remains limited, however. A small series from Lebanon reported on 14 pregnant patients injured by high-velocity bullets or shrapnel, among whom three were managed expectantly, at 25, 32, and 34 weeks: All three fetuses survived and eventually delivered vaginally.[36] The authors note that expectant management in these cases was predicated on the absence of major fetal injuries as shown by X-ray or ultrasound imaging. Outcomes were better than those in which immediate cesarean was undertaken, though the decision to take the patient to surgery was confounded by indication: That is, there was "fetal distress" in two cases, bullet-induced fetal fractures in two, two traumatic uterine ruptures, and in two cases the uterus had to be emptied to get surgical access to a maternal injury in the liver or retroperitoneum. Three other cases in which cesarean was undertaken without either a fetal indication for cesarean or a clear maternal indication for laparotomy all resulted in stillbirth.

Intraoperative fetal monitoring is sometimes used during nonobstetric surgery but cannot be routinely recommended. Not only is it technically and logistically difficult to perform during abdominal surgery, but it raises the possibility that concerns about fetal well-being may trump concerns about maternal stability. The Committee on Obstetric Practice of the American College of Obstetricians and Gynecologists states, "The decision to use fetal monitoring should be individualized," and points out that all the following must apply if it is to be undertaken: "The fetus is viable; it is physically possible to perform intraoperative fetal monitoring; a health care provider with obstetric surgery privileges is available and willing to intervene during the surgical procedure for fetal indications; when possible, the woman has given informed consent to emergency cesarean delivery; the nature of the planned surgery will allow the safe interruption or alteration of the procedure to provide access to perform emergency delivery."[37]

CARDIAC ARREST

In the event of cardiopulmonary arrest of a patient past mid-pregnancy, effective cardiopulmonary resuscitation is difficult to achieve. Aortocaval compression by the uterus interferes with return to the heart when the patient is supine. Left uterine displacement has been advocated, with a wedge under the right hip, but manual uterine displacement from above is more effective.[38] Chest compressions and ventilations should be delivered according to standard protocols.

There is good evidence to recommend expedited delivery of the fetus within 4 minutes of arrest for *both maternal and fetal benefit*, especially after the threshold for neonatal viability (>24 weeks) or in the case of a potentially reversible cause of maternal arrest. Recent clinical practice guidelines from the SOGC[23] and from the American Heart Association[38] emphasize the role of perimortem cesarean delivery in improving the chances for return of spontaneous circulation in the mother as well as the outcome for the perinate.

The push for perimortem cesarean delivery (PMCD) within 4 minutes of maternal cardiac arrest originated from a seminal paper published 30 years ago.[39] The authors outlined the potential maternal and fetal benefits and targeted a time of 4 minutes to begin the procedure, 5 minutes to effect delivery. This target reflected the difficulty of performing effective cardiopulmonary resuscitation (CPR) in a gravid patient past midpregnancy and the time threshold believed to apply for maternal and fetal oxygen reserve. Subsequent case series have reported return of spontaneous circulation after aortocaval compression is relieved with delivery of the fetus. Katz[40] reviewed more than 200 cases of maternal cardiac arrest and found only three cases in which effective CPR was achieved prior to delivery of the fetus.

As far as the fetus is concerned, ischemic brain injury occurs 4–5 minutes after cessation of blood flow, and the hope is that neurologic injury to the fetus may be prevented if it is delivered within that time frame.[39] Neonatal survival with normal neurological development has been documented, however, even 30 minutes after maternal arrest,[41] so delivery should not be considered futile if more than 5 minutes have passed.

In nonresuscitatable causes of maternal CPA (e.g., massive trauma), perimortem cesarean section should be performed immediately for the benefit of the fetus. Nonobstetric providers can employ a 'two fingerbreadth' rule if they need to estimate viability: Palpation of the uterine fundus two fingerbreadths above the umbilicus approximates 24 weeks gestation, at which time extrauterine survival is possible.

AU:3

Once the decision is made to proceed with PMCD, no delay should be made to check fetal heart rate or move the patient to the operating room. Ultrasonography is difficult to perform in such a setting and only wastes crucial time. Neither sterile technique nor anesthesia is required, and the consent of the mother will, obviously, be impossible. Neonatology providers should be informed and urgently available, but the procedure should not wait for them to arrive. CPR should be continued during the procedure and the obstetrician or delivering physician should perform laparotomy in a manner they are most comfortable with.[38]

Either midline vertical or Pfannenstiel (transverse) incision can be utilized, according to the operator's preference, as long as speed can be achieved. After delivery of the fetus, the placenta should be delivered and the uterus closed with care to prevent bladder and bowel injury in potentially resuscitable cases. While there will be no bleeding during the surgery, because there will have been no circulation, hemorrhage is possible after return of spontaneous circulation.[42] The surgeon should be prepared to treat both uterine atony and coagulopathy.

The ethics and legality of PMCD have been addressed by others[40,42] and will be mentioned here briefly. In cases of fatal nonresuscitatable maternal trauma, the medical provider's obligation to the fetus should be obvious and would require immediate action. In cases where maternal resuscitation is possible, though PMCD may appear morbid and even barbaric, the evidence is clear on its potential both as an aid to maternal resuscitation and as a tool to deliver a liveborn baby. In terms of legality and consent, as of 2012 no instances of legal action (either civil or criminal) have been entered against a physician for performing PMCD. However, there are cases in which physicians have been sued either for not performing PMCD or not doing so in a timely manner.[40]

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AU:1 Page No 478 Please spell out CDC and EMS.
AU:2 Page No 479 Please spell out IVC.
AU:3 Page No 483 Please spell out CPA.