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A Case Report: Emergency Management of a Pregnant Trauma Patient—An Anesthesiologist's Perspective and Role

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Abstract

Trauma is the leading cause of death for all women of childbearing age. Motor vehicle accidents account for almost two-thirds of all maternal non-obstetric, trauma-related deaths, while falls and domestic violence comprise a large percentage of the rest. The leading causes of obstetric trauma are motor vehicle accidents, falls, assaults, and gunshots, and ensuing injuries are classified as blunt abdominal trauma, pelvic fractures, or penetrating trauma . The causes are different with different life styles and different socio-economic and cultural background. Pregnant trauma victims tend to be younger, less severely injured, and more likely African American or of Hispanic descent compared with nonpregnant victims of trauma. Drugs and alcohol are a factor in about 20 percent of maternal trauma. With pregnancy comes the challenge and responsibility of caring for two patients at once, the mother and the fetus. In general, providing optimal maternal care is the best strategy to optimize fetal survival. Decision-making including the condition of the mother, gestational age, status of the fetus, and interventions are based on these key factors. Many providers are involved in the care of the pregnant patient: at the trauma scene, in the emergency department, and in the operating room. The anesthesiologist plays a key role in the care and management of the pregnant trauma patient. All anesthesiologists have ample training in obstetric anesthesia during their residency and frequently cover obstetric units in hospitals where pregnant patients are cared for. On the other hand, most nonobstetric physicians have little obstetric exposure and may be uncomfortable caring for the pregnant patient because of unfamiliarity with the physiologic changes of pregnancy or the evaluation of fetal well-being. This is

not only a source of stress for other trauma providers, but can put maternal well-being at risk. Non-obstetric physicians may hesitate to order necessary diagnostic and therapeutic interventions for fear of doing the "wrong thing," all because the patient is pregnant. A multidisciplinary approach to the pregnant trauma patient involving trauma surgeons, obstetricians, anesthesiologists, emergency medicine, and other providers, is critical to deliver optimal care and achieve the best outcomes for both the mother and the baby. In summary, a multidisciplinary approach to provide optimal maternal care will facilitate to achieve the best outcomes for the mother and is also the best strategy for optimizing fetal survival. The following is a case report of a pregnant trauma patient who needed immediate intervention because of massive placental abruption when only a minimal workup was completed because of the urgency of the situation.

Keywords

Obstetric Anesthesiology, Ob Trauma, Maternal and Fetal Resuscitation

1. Introduction

Trauma in pregnancy is the leading cause of non-obstetrical maternal death and remains a major cause of fetal demise. Traumatic injury in pregnant females can result in high maternal and fetal mortality, up to 73% following penetrating abdominal injuries and 66% in blunt pelvic injuries [1]. Non-lethal injuries occur in 1 in every 12 pregnant women and are most commonly the result of a motor vehicle accident or of domestic or intimate partner violence [1]-[6]. It is essential to be aware of the fact that nonfatal injuries also occur and research indicates 1 in every 12 pregnancies survive nonlethal trauma. The most common mechanism for nonfatal injuries is motor vehicle accidents [7] [8]. Successful patient outcomes in trauma depend upon prompt response and well-coordination of multiple teams involving trauma surgeons, obstetricians, anesthesiologists, emergency medicine, neonatologists, and other providers, which is critical to deliver optimal care and achieve the best outcomes for both the mother and the baby.

The following is a case report of a pregnant trauma patient who needed immediate intervention because of massive placental abruption when only a minimal workup was completed because of the urgency of the situation.

2. Preoperative Evaluation

A 33-years-old African American female presented to the ED after being struck by a motor vehicle while crossing the street with her son. A Level 2 trauma code was activated immediately. She was struck on her left side and denied any loss of consciousness at any point. She was at 34 weeks of gestational age. Her initial complaints were "pain all over the body", however, worse in her chest, back, and left arm, which she was unable to move. The patient denied any significant

medical conditions. Her surgical history was significant for a cesarean section two years ago.

On examination, her Vital Signs were as follows: Heart rate: 90 per minute, BP 124/82 mm of Hg, Respiratory rate: 22 per minute, Pulse oximetry: 90%, and Oral Temperature: 97.8.

The patient presented with a Glasgow Coma scale of 15. Bruises and lacerations were noticed on the left upper extremity, right and left elbows, left side of the abdomen, and right knee. Examinations of other systems were within normal limits. The patient was placed on a non-rebreather mask with 1005 oxygen masks with improvement of pulse oximeter readings to 97% - 98%.

Obstetric care team evaluated the parturient and the fetus on arrival and noted that the fetal heart rate was 70 - 80 beats per minute. In the interim, ER trauma team had obtained FAST scans and CT head and neck and no evidence of cervical spine fracture was found. Obstetric care team was concerned about the low fetal heart rate and non-reassuring baseline variability and initiated in-utero resuscitation of the fetus inclusive of maternal fluid bolus, left uterine displacement to relieve aortocaval compression and optimization of maternal blood pressure. A quick abdominal ultrasound was performed which relieved evidence for partial placental separation. Despite all these measures, the fetal heart rate tracing continued to be non-reassuring. A team decision was made to take the patient to the obstetric suite for an emergency C-Section. Trauma team and obstetric care team accompanied the patient to the obstetric suite.

3. Intraoperative Management

The patient was rushed to the OR for emergent Cesarean section and exploratory laparotomy. There was concern for placental abruption in the setting of fetal bradycardia. The patient arrived in to the OR with two 18G intravenous catheters and one 20G intravenous catheter and crystalloid fluid infusing. A cooler from the blood bank containing blood products for massive transfusion arrived with the patient.

Anesthetic management:

Optimum management requires a thorough understanding of normal maternal-fetal physiology, maternal physiologic adaptation to pregnancy (Table 1), fetal physiologic requirements, will have a significant impact on the decision-making process. Altered drug pharmacodynamics and pharmacokinetics, the increased oxygen requirements, decreased functional residual lung capacity and increased risk for aspiration associated with pregnancy complicates perioperative management by decreasing the time available and the margin of safety.

Keeping in mind the multiple injuries our patient had sustained, we were concerned regarding significant internal bleeding and hemodynamic stability fluid resuscitation was initiated utilizing rapid infusers and one unit of PRBC transfusion was started, along with preoxygenation with 100% oxygen. Pre-induction vital signs were as follows: BP 120/100 mm of Hg, Heart rate 101 beats/minute,

Table 1. Physiologic changes of pregnancy.

Cardiovascular	Hematologic	Pulmonary
Decreased SVR: In the 1st trimester progressively drops 35 - 40 percent hitting plateau in mid-2nd trimester	**Plasma volume:** Increases reaching peak at 30 - 34 weeks **Total intravascular volume increases ~50%	**FRC:** Decreases ~20% during 2nd half of pregnancy as a result of ERV & RV decrease
Increased CO: Peaks in the early third trimester, HR increases ~25% from patient baseline	**RBC mass:** Increase starting 8 - 12 weeks and steadily continues to do so until the end of pregnancy, increasing by 20% - 30%.	**Ventilation:** Resting MV increases by nearly 50%, this results mainly from larger TV (~40% increase) while RR remains largely unchanged
MAP: Remains fairly constant throughout pregnancy	**Physiologic Anemia:** Relative increase in plasma compared to RBC mass	**Oxygen consumption:** Increases approximately 20%
	Prothrombotic state: Increased prothrombotic factors including fibrinogen, factors II, VII, X, XII and VWF Decreased anticoagulant factors including protein S and reduced fibrinolysis via increased fibrinolytic inhibitors including thrombin activatable fibrinolytic inhibitor, PAI-1 and PAI-2	**Minor changes with little clinical significance have been found in the following: VC, TLC, and diffusing capacity

Pulse oximetry 98%, and respiratory rate 25 per minute. After preoxygenation, general anesthesia was induced with rapid sequence method and utilizing cricoid pressure for intubation. Induction was performed with Propofol 200 mg, Fentanyl 100 mcgs, and Succinylcholine 120 mg. In-line stabilization was performed by an assistant Intubation was achieved on the first attempt with a video laryngoscope with a size 7 endotracheal tube. End-tidal CO_2 ($EtCO_2$) was confirmed by waveform capnography. Shortly after induction, the patient was given 50 mg Rocuronium and two grams of Cefazolin. For PONV prophylaxis, patient received dexamethasone 4 mg and ondansetron 4 mg.

Within a few minutes after endotracheal intubation and positive pressure ventilation, the pulse oximeter oxygen saturation decreased from 99 to 78 rapidly. The immediate concern was impending tension pneumothorax, there was not sufficient time in the ER for performing a Chest X-Ray to rule out pneumothorax. After assuring that there was a continued presence of $EtCO_2$, auscultation of the lung fields showed the presence of breath sounds bilaterally. Peak Inspiratory pressure was noted to be 34 cms of water. During this episode, vital signs are as follows: Heart rate was 92 beats per minute and BP 130/100 mm of Hg. No distended neck veins were observed. These clinical findings were reassuring and tension pneumothorax was ruled out. Incidentally, the endotracheal tube was noted to be at 22 cms and it was pulled back to 20 cms. Pulse oximeter oxygen saturation improved to 98% with continued positive pressure ventilation with 100% oxygen. At this time, fluoroscopy was called for in the Main OR. Trauma surgery team was made aware and decision was made not to place a chest tube at that point.

A baby boy was delivered two minutes after incision. Oxytocin infusion was started at 40 units/hours and 250 mcg of prostaglandin F2-alpha was administered. After successful delivery of the baby and placenta, the trauma surgery team initiated the exploratory laparotomy. The surgical team noted diffuse oozing and bleeding. Concern was expressed by the obstetric team regarding hypocoagulability, secondary to placental abruption. A right radial arterial line was inserted and one unit of Fresh Frozen Plasma (FFP) was transfused. Throughout the surgery, the patient was given boluses of Fentanyl, totaling 300 mcg. The patient remained hemodynamically stable throughout the surgery without requiring any vasopressor support with mean arterial pressure (MAP) ranging from 74 - 98 mm of Hg and HR ranging from 85 - 121 beats/minute. The surgery team did not find any active source of bleeding and opted to use hemostatic agents and monitor for hemostasis. At the end of the case, the patient was given 4 mg Morphine, and 1000 mg Acetaminophen for postoperative pain management. Still waiting for fluoroscopy to image the lungs and the left upper extremity and chest.

The patient had stable vital signs and bilateral clear breath sounds and therefore the decision was made to extubate the patient. The patient was reversed with Neostigmine 3 mg and Glycopyrrolate 0.6 mg and was extubated uneventfully. The total fluid management for the case was: 3 liters of LR, 1.5 liters of 0.9% sodium chloride, 1 U PRBC, and 1 U FFP and the estimated blood loss (EBL) was 1200 ml.

The patient was transported to the radiology suite from the OR for imaging of the chest in stable condition. Post-operative vital signs were: Blood pressure, 133/60; Heart rate, 87; SpO_2, 97%; Respiratory rate, 20; temperature, 98 F. The patient was awake and responsive and she reported zero pain.

4. Postoperative Course

After she was successfully extubated, she was transported to radiology suite for imaging of the left upper extremity and chest. Imaging showed multiple fractures in the left humerus and right apical pneumothorax, right pleural effusion, and multiple right-sided rib fracture deformities. Left upper extremity sling was placed for segmental humeral shaft fracture, admitted to the surgical step-down unit with an abdominal wound vac and right-sided pigtail. With Trauma surgery as the primary team, the patient was closely followed by OBGYN, Orthopedic surgery, and Anesthesiology. Post operatively, the patient was comfortable but persistently tachycardic with HR 100 - 120 s. She was adequately resuscitated with crystalloids and received an additional 2 units of PRBC for a hematocrit of 24.8 and then on, she was hemodynamically stable.

For pain control, the patient was started on Dilaudid, PCA, oral acetaminophen, and lidocaine patches. The patient remained stable and continued to improve. There were no signs of significant additional bleeding and the drains had minimal output. Dilaudid PCA was eventually transitioned to PO medication.

Five days after initial C-Section and exploratory laparotomy, the patient underwent left humeral ORIF under general anesthesia with ETT. She received an infraclavicular block with Bupivacaine 0.25% 20 ml and liposomal Bupivacaine 10 ml for postoperative pain management. She tolerated the procedure well and was successfully extubated.

The pneumothorax continued to decrease in size and the chest tube was removed on POD 6 for exploratory laparotomy and C-Section. Wound vac was also removed and the laparotomy incision packed with wet-to-dry dressings. Her abdomen has remained soft, nondistended, and appropriately tender throughout her hospital course. Her incision healed well without erythema, induration, or drainage.

She was discharged on post-op day 10 to go home for physical therapy. The patient followed up with trauma surgery, OBGYN, and orthopedic surgery multiple times in the outpatient setting for continued follow-up. Her midline incision as well as the low transverse incision is healed well.

This extensive, convoluted postoperative course of this patient highlights the importance of heightened vigilance, ongoing evaluation of the clinical picture to address other injuries the patient might have sustained and provide optimal care for these injuries. Apart from providing optimal timely clinical care, these patients need counseling regarding post-traumatic stress and support to overcome the emotional trauma of the accident including premature birth of the child. Our patient was followed by a trauma psychologist in the outpatient clinic.

5. Discussion

The anesthetic challenges of this case were multifaceted. We had a pregnant patient requiring emergency Cesarean section, simultaneous resuscitation, potential associated injuries and insufficient time in ED to evaluate these associated injuries.

Many providers are involved in the care of the pregnant patient: at the trauma scene, in the emergency department, and in the operating room (**Table 2**). The anesthesiologist plays a key role in the care and management of the pregnant trauma patient. All anesthesiologists have ample training in obstetric anesthesia during their residency and frequently cover obstetric units in hospitals where pregnant patients are cared for. On the other hand, most nonobstetric physicians have little obstetric exposure and may be uncomfortable caring for the pregnant patient because of unfamiliarity with the physiologic changes of pregnancy or the evaluation of fetal well-being. This is not the only a source of stress for other trauma providers, but can put maternal well-being at risk. Non-obstetric physicians may hesitate to order the necessary diagnostic and therapeutic interventions for fear of doing the "wrong thing", all because the patient is pregnant. As emphasized before, a multidisciplinary approach to the pregnant trauma patient involving trauma surgeons, obstetricians, anesthesiologists, emergency medicine, and other providers, is critical to deliver optimal care and achieve the best outcomes for both the mother and the baby.

Table 2. Initial assessment and evaluation of the pregnant trauma patient. Advanced Trauma Life support guidelines 10th edition.

Mother:	Fetus:
Ensure patent airway, adequate ventilation and oxygenation, volume status, intubation may be necessary	Abdominal examination is of critical importance in assessing fetal wellbeing, as the main cause of fetal death results from maternal shock and maternal death
Manual displacement of the uterus to the left to reduce IVC compression, if spinal motion restriction is deemed necessary logroll to the left 15 - 30 degrees	Evaluate for abdominal tenderness, rigidity, guarding and rebound tenderness, which may be signs of the feared complication of placental abruption.
Ensuring mother volume status is vital to placental perfusion and thus fetal perfusion	other concerning conditions include transverse lie, palpation of fetal parts and US showing retroplacental hematoma
Baseline lab evaluation including fibrinogen levels, which can help elucidate early DIC -Kleihauer-Betke test -FAST exam -Consider CT	Fetal heart rate monitoring is crucial, fetal nonreassuring patterns is an ominous sign

Awareness of the unique physiologic changes of pregnancy and how it can alter the clinical picture in a pregnant, trauma patient is an essential component and Advanced trauma Life Support (ATLS) algorithms can assist in guiding this coordination and resuscitation [9] [10].

Unlike typical trauma cases, the care team is tasked with caring for two patients at once. In general, a multidisciplinary approach to provide optimal maternal care will facilitate to achieve the best outcomes for the mother and is the best strategy for optimizing fetal survival.

6. Ethical, Clinical and Moral Dilemmas When Taking Care of a Pregnant Trauma Patient

There are many ethical and clinical dilemmas that surround the management of a pregnant trauma patient. First and foremost, ethical care should aim at ensuring that the woman remains responsible for herself and her fetus and that she retains her trust in the health professionals providing her care: it is not right to attempt to use the courts to force a competent woman to have treatment against her will, as the case may be. All female trauma patients between the ages of 10 and 55 years warrant Beta-human chorionic gonadotropin (HCG) testing. It is critical to understand that the risk of a missed injury or delay in diagnosis is much greater to the fetus and appropriate diagnostic tools inclusive of use of X-Rays and other imaging studies should be initiated as early as possible, in the evaluation of a pregnant trauma patient. Radiographic imaging is often indicated in pregnant patients, especially those whom have sustained traumatic event [11]. However, due to the fear of potential teratogenic and deleterious effects of io-

nizing radiation practitioners are often hesitant to order appropriate studies.

American College of Obstetricians and Gynecologists (ACOG) has committed to following guidelines for diagnostic imaging during pregnancy:

1) Women should be counseled that X-ray exposure from a single diagnostic procedure does not result in harmful fetal effects. Specifically, exposure to < 5 rads has not been associated with an increase in fetal anomalies or pregnancy loss.

2) Concern about possible effects of high-dose ionizing radiation exposure should not prevent medically indicated diagnostic x-ray procedures from being performed on a pregnant woman. During pregnancy, other imaging procedures not associated with ionizing radiation (eg, ultrasonography, MRI) should be considered when appropriate.

3) Utrasonography and MRI are not associated with known adverse fetal effects.

4) Consultation with an expert in dosimetry calculation may be helpful in calculating estimated fetal dose when multiple diagnostic x-rays are performed on a pregnant patient.

5) The use of radioactive isotopes of iodine is contraindicated for therapeutic use during pregnancy.

6) Radiopaque and paramagnetic contrast agents are unlikely to cause harm and may be of diagnostic benefit, but these agents should be used during pregnancy only if the potential benefit justifies the potential risk to the fetus.

7. Obstetric Concerns

The trauma team must include providers familiar with the complications related to maternal trauma. Placental abruption, for example, is a major concern in abdominal trauma (**Table 3**) [12] [13] [14] [15]. The pregnant patient may not exhibit significant symptoms initially. The fetus meanwhile may suffer serious compromise or even death. If not quickly recognized, placental abruption can eventually lead to maternal hypovolemia, hypotension, hypoxemia, and death from exsanguination. Abruption is but one of a number of sequelae related to pregnancy that the trauma team must be prepared to deal with. And these challenges get amplified when the essential work-up of the trauma patient for other injuries like ruling out C-Spine injury, major bone fractures, injuries to vital organs, is not completed in the essence of the time and urgency to respond to an unstable fetus, as was the case with our pregnant trauma patient.

SURGICAL INTERVENTION AND ROLE OF ANESTHESIIOLOGISTS

One of the main decisions in managing the pregnant trauma patient is: does the patient need an exploratory laparotomy? If there is no evidence of peritoneal penetration or a ruptured intraabdominal organ, using physical exam, ultrasound/radiologic criteria, and/or positive DPL, then injury to the uterus or fetus is unlikely and surgical exploration is not indicated.

When surgical exploration is necessary to evaluate the type and severity of

Table 3. Placental abruption. Incidence 3 - 10 per 1000 births of which 2/3 are considered to be severe.

Clinical Manifestations/Findings:	Consequences/Complications:	Management:
Vaginal bleeding, abdominal pain accompanied by uterine contractions including tachysystole, uterine tenderness, nonreassuring fetal heart rate pattern	**Maternal** Excessive blood loss, DIC, both leading to hypovolemic shock, AKI, ARDS, multiorgan failure, peripartum hysterectomy and death	-Immediate continuous FHR monitoring, IV access establishment, keep patients warm, supplemental O2 use as necessary, attempt quantification of blood loss, lab testing of CBC, type and screen, crossmatch as necessary, coagulation studies, liver studies,
US finding of retroplacental hematoma has a PPV of ~90%, but has low sensitivity 25% - 60%	Postpartum consequences include increased long-term risk of premature CV disease and increased mortality at earlier age	Replacement with blood products as necessary, with targets as follows: hematocrit > 25% - 30%, platelet count > 75,000, fibrinogen > 300 mg/dL, PT and aptt < 1.5x control
	Fetal: -Increased perinatal morbidity and mortality related to hypoxemia, asphyxia, low birth weight and/or preterm birth **perinatal mortality ~3% - 12%	Ultimately cesarean section may be needed to control issue and protect both mother and fetus

penetrating injuries, cesarean delivery may be required for the following situations: Uterine size prohibits adequate abdominal exploration, when necessary for the repair of an extrauterine injury, for repair of a uterine injury in a woman with a viable fetus, an injured and/or distressed viable fetus and maternal cardiac arrest with a fetus of more than 23 weeks not responding to initial resuscitative efforts.

ANESTHETIC MANAGEMENT

Anesthesia consultation should be sought early even if maternal injuries are considered minor and the patient is admitted to labor and delivery only for observation and fetal monitoring. Early evaluation of the patient for possible anesthesia risks is essential so the anesthesia team can be prepared should surgical intervention be suddenly required.

AIRWAY MANAGEMENT OF THE PREGNANT TRAUMA PATIENT

For the pregnant trauma patient, the anesthesiologist utilizes the American Society of Anesthesiologist's (ASA) algorithm for difficult airway management with modifications related to the gestational effects of pregnancy [16]. Difficult tracheal intubation occurs more frequently in the parturient (1:2500), and the incidence of failed intubation is 1:300, or eight times higher than in nonpregnant patients. Should trauma occur to the face, cervical spine, or neck, one would expect the level of difficulty to only increase.

If possible, airway management is ideally instituted in the operative setting where all tools for difficult airway management should be available. Supplemental O_2 is instituted with suction immediately available. Experienced personnel should be present to assist in airway management. If the patient is hypoxemic, has decreased ventilatory effort, is unable to clear secretions due to decreased level of conscience or loss of protective airway reflexes, or has airway obstruction, then intubation should proceed rapidly. If significant difficulty in airway

management is clearly anticipated, an alternative airway such as cricothyroidotomy or tracheostomy may be necessary, ideally performed by an experienced, skilled surgeon.

Should cervical spine injury be present or suspected, all precautions to prevent unnecessary movements of the neck are employed. Awake fiberoptic intubation can be done to minimize neck movement and decrease the risk of aspiration. Topicalization with local anesthetics will facilitate airway manipulation. Benzocaine can be used for topicalization but caution with dosing is needed as methemoglobinemia can occur with large doses. If indicated, small doses of midazolam can be safely used with minimal effect on the neonate. Nasotracheal fiberoptic intubation can be performed if no trauma to the face has occurred that would preclude this approach. But the nasal approach should be done with caution and the oral approach may be preferred. This is due to swelling of the nasal mucosa in pregnancy that increases the likelihood of bleeding in this area, making visualization potentially much more difficult. Orotracheal fiberoptic intubation is the alternative method of choice. Should secretions and blood obstruct the view of the airway, retrograde oral intubation is another option.

Head trauma, shock, alcohol, and drug abuse can all contribute to an uncooperative patient that may make awake fiberoptic intubation not only unrealistic, but potentially dangerous. Patients that are combative can move during attempted intubation with the potential of causing or worsening neurologic injury. RSI with cricoid pressure and inline stabilization of the cervical spine is frequently and successfully utilized in the pregnant trauma patient. If time permits, and no contraindications are present, gastrointestinal prophylaxis should be considered prior to airway management, including the use of an H2 receptor antagonist, metoclopramide, or a nonparticulate oral antacid such as sodium citrate. Preoxygenation prior to induction is mandatory, and alternate methods of airway management must be immediately available should intubation prove difficult.

Operative anesthetic management of pregnant trauma patients includes all principles of anesthetic management of trauma patients as well as the principles of the pregnant patient undergoing nonobstetric surgery (**Table 4**). Patients may be fearful of anesthesia effects on the fetus and need reassurance that anesthesia itself is not in and of itself a cause of fetal loss or a significant risk of fetal malformations even early in gestation. Preoperative pain medication and anxiolytics as indicated should be used as elevated maternal circulating catecholamines from stress can potentially compromise uterine blood flow. All standard monitors should be used for surgery. Anesthetic goals include meticulous attention to details of airway management, ensuring adequate maternal cardiac output/blood pressure/perfusion, and avoiding hypotension and hypoxemia. PCO_2 should be maintained in the normal range as hyperventilation/hypocarbia/alkalosis may decrease uterine perfusion and fetal oxygenation.

Fetal monitoring intraoperatively is done on a case-by-case basis once the fetus is considered viable. Unfortunately, with abdominal procedures or in

Table 4. Principles of anesthetic management of pregnant trauma patients.

Restoration of blood volume and tissue perfusion
Protection of brain and spinal cord
Maintenance of uteroplacental circulation and fetal oxygenation
Prevention of maternal awareness
Correction of coagulopathy
Maintenance of normothermia
Avoidance of teratogenic drugs (during the first trimester)
Detection of unrecognized injuries

urgent situations, monitoring may not be practical. Fetal monitoring in and of itself has not been shown to improve fetal outcome. Beat-to-beat variability, a highly sensitive indicator of fetal well-being, will be commonly lost under anesthesia and is a normal finding. Fetal bradycardia, however, is not expected and once it occurs, maneuvers to improve maternal circulation/placental perfusion/fetal oxygenation should be instituted to try to resolve it. These measures can include assuring adequate left uterine displacement, raising maternal blood pressure, increasing the inspired fraction of oxygen, and ensuring that surgical retraction/intervention is not a factor [17] [18]. Emergent Cesarean delivery may be necessary if bradycardia does not resolve.

CPR IN PREGNANCY AND PERIMORTEM CESAREAN DELIVERY

Cardiac arrest occurs in approximately 1 in 30,000 pregnancies [19] [20]. The incidence is higher among those with cardiovascular disease. In the setting of trauma, cardiac arrest can occur from multiple causes including hemorrhagic shock, respiratory compromise, and tension pneumothorax. The likelihood of survival is influenced by the timeliness and expertise of the resuscitation team. Obstetricians, anesthesiologists, neonatologists, and nursing staff must work efficiently and in an organized fashion to resuscitate these patients [21]. As these events happen unexpectedly, cooperation is essential to assemble the needed equipment and perform resuscitation in the labor suite. When arrest occurs "in the field" – the obstetrical trauma team, with all necessary equipment, must be on standby in the emergency department for patient arrival in the event that emergency Cesarean delivery may be indicated to assist in maternal resuscitation (**Table 5**).

The physiologic changes of pregnancy place the pregnant patient at significant risk of difficulty in resuscitation, should maternal arrest occur. The patient will rapidly become hypoxemic, and the uterus will obstruct some venous return during CPR, especially late in pregnancy, even if left uterine displacement is instituted. The uterus shunts anywhere from 20 percent to 30 percent (as opposed to prepregnancy levels of 0.5% - 1.0% of cardiac output). Normal CPR, in the best of circumstances, can generate 25 percent of normal cardiac output. In pregnancy, a cardiac output of up to 30 percent or more, with the uterus taking

Table 5. Principles of cardiopulmonary resuscitation (CPR) pregnancy.

1. Intubate the trachea soon after initiation of CPR, to facilitate oxygenation and ventilation and to prevent aspiration.
2. Before 24 weeks, the rescuer should be concerned mainly to save the mother.
3. After 24 weeks, the goals of resuscitation should be to save both the mother and the fetus.
4. Maintain left uterine displacement during CPR.
5. According to AHA guidelines, a resuscitative measures should be followed including a ventricular defibrillation algorithm and the use of vasopressors such as epinephrine, norepinephrine, and dopamine.
6. If initial efforts at resuscitation are unsuccessful, consider immediate delivery of the fetus. Optimal time from arrest to delivery is under 5 minutes. Understand that cesarean delivery is to facilitate maternal resuscitation.
7. Cesarean delivery facilitates resuscitation by restoring venous return, decreasing metabolic demand, and allowing more effective chest compression.
8. If after delivery resuscitation is still ineffective, consider open-chest cardiac massage and cardiopulmonary bypass.

such a large percentage, will potentially rob other maternal organs of adequate perfusion with CPR. Just the anatomic configuration of the patient with the gravid uterus and reduced chest wall compliance may interfere with proper positioning/performance of effective CPR.

Basic life support and advanced life support protocols should be instituted (Table 5). In general, CPR in the pregnant patient follows the same resuscitation protocols [22] [23] [24]. If spinal injury is present, manually displacing the uterus by hand may be one possible remedy. Shifting of the entire bed or backboard to one side may help relieve aortocaval compression, but may interfere with maintaining the proper positioning for chest compression. Energy requirements for defibrillation appear to be similar as in nonpregnant states. The fetus is not harmed if the paddles are placed properly. If a fetal scalp monitor has been placed, the lead should be disconnected from the fetal heart rate monitor prior to defibrillation.

Use of sodium bicarbonate during resuscitation to reverse metabolic acidosis is controversial because of evidence that it may worsen maternal intracellular acidosis in cardiac arrest. Sodium bicarbonate does not readily cross the placenta and will likely not have a significant effect on the fetus. The most important consideration is restoration of placental perfusion and oxygen delivery to reverse fetal acidosis.

A multidisciplinary approach to these patients using a designated "obstetric trauma care team" will offer both the mother and fetus the greatest chance of successful outcome. The anesthesiologist with expertise in airway management, critical care, and physiologic changes of pregnancy can be a vital member of the trauma team. Initial resuscitative efforts will be directed at the mother with em-

phasis on maintaining uteroplacental perfusion and fetal oxygenation. The best maternal resuscitative efforts ensure better fetal outcome.

The decision to perform perimortem cesarean delivery should be based on the viability of the fetus, certainty of maternal death or unfavorable neurologic outcome, and duration of cardiac arrest [25]. When cesarean delivery is being initiated, it is imperative that CPR be continued at optimal levels. Survival of the fetus after perimortem Cesarean delivery:

- 70 percent when delivered less than 5 minutes.
- 13 percent within 6 to 10 minutes.
- 12 percent within 11 and 15 minutes.

8. Summary

The pregnant trauma patient presents unique challenges to the trauma anesthesiologist. Pregnancy is associated with specific physiologic changes and unique injuries that must be considered along with concern for the developing fetus. A multidisciplinary approach to these patients using a designated "obstetric trauma care team" will offer both the mother and fetus the greatest chance of successful outcome. The anesthesiologist, with expertise in airway management, critical care, and physiologic changes of pregnancy can be a vital member of the trauma team. Initial resuscitative efforts will be directed at the mother with emphasis on maintaining uteroplacental perfusion and fetal oxygenation. The best maternal resuscitative efforts ensure better fetal outcome. In the event of cardiopulmonary arrest, if the pregnant patient does not respond within the first 4 minutes of CPR and the fetus is viable, emergency cesarean delivery should be considered to maximize both maternal and fetal chances of survival.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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