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Anesthetic Management and Challenges in the Pregnant Patient

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Abstract Trauma during pregnancy is the leading cause of non-obstetric morbidity and mortality and presents a unique set of challenges to the anesthesiologist, as there are inherently two patients to care for. The best treatment for the fetus is expeditious evaluation and resuscitation of the mother. Evaluation of the fetus by an obstetrician should be part of the secondary survey, including fetal heart rate monitoring for pregnancies exceeding 20 weeks gestation. The duration of fetal heart rate monitoring should be guided by the severity and mechanism of injury, as well as by maternal and fetal responses. Pregnancy brings about a multitude of physiologic changes that must be considered when evaluating and treating the pregnant trauma patient. The anesthesiologist may have more familiarity with the physiology of pregnancy and can play an important role in resuscitation. The initial goals of resuscitation are maintenance of adequate ventilation and oxygenation, volume replacement, and avoidance of aortocaval compression.

Keywords Anesthesia · Pregnancy · Trauma · Placental abruption · Motor vehicle crash · Resuscitation · Fetal monitoring · Perimortem C-section · Burn injury

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Introduction

Trauma is the primary cause of maternal or fetal demise, with an incidence of approximately 7–8 % of all pregnancies in the United States [1••, 2, 3]. Almost one-quarter to one-third of patients who are hospitalized for traumatic injuries will deliver their child during their hospital stay [1••, 4]. There are several known risk factors for experiencing trauma during pregnancy, including a history of abuse, unintended pregnancy, unmarried status, race, substance abuse, low maternal education level, and lower socioeconomic status [1••, 4]. The three most common significant causes of trauma to the pregnant female include motor vehicle accidents, which account for 50 % of all traumas, falls, and intentional trauma [1••, 2, 4]. Intentional trauma, otherwise known as intimate partner and domestic violence, accounts for 22 % of all traumatically injured pregnant women [2]. Even relatively minor trauma during pregnancy increases the risk of preterm premature rupture of membranes, placental abruption, uterine rupture, and maternal and fetal death [1••, 3–5]. The increased risk to the fetus does not end after stabilization of the mother and discharge from the hospital. Patients who sustain trauma during pregnancy are at an increased risk of having an abruption, premature delivery, or babies with a low birth weight [4].

Physiologic Changes of Pregnancy

Numerous changes take place in almost all organ systems during pregnancy due to mechanical effects of the enlarging uterus, hormonal changes, and increased metabolic demands (Table 1). Maternal blood volume increases 45 % but the increase in red blood cell mass is not proportional, resulting in a relative anemia [6]. By the end of the third

trimester, hematocrit is typically 30–34 %. Resting heart rate is 15–20 beats per minute more in the third trimester, with an increase in cardiac output of 30–50 %. Blood pressure decreases about 15 mmHg in the second trimester and gradually increases toward pre-pregnancy levels by the end of the third trimester [7]. After 20 weeks, the gravid uterus can cause significant aortocaval compression in the supine position; patients who are 20 weeks or more pregnant should be placed in the left lateral decubitus position.

The respiratory system also undergoes many changes during pregnancy. Oxygen consumption increases 15–20 % to compensate for the increased metabolic demand and oxygen delivery to the fetus. Respiratory rate is increased, causing a relative respiratory alkalosis ($PaCO_2$, 27–32 mmHg) with compensatory metabolic acidosis (kidneys increase bicarbonate excretion) [7]. Thus, mechanically ventilated patients will need their minute ventilation increased to target a $PaCO_2$ between 27 and 32 mmHg. Tidal volumes are increased by 40 %, but residual volume is decreased due to the gravid uterus, resulting in 20–25 % decrease in functional residual capacity. This decrease in functional residual capacity, coupled with increased oxygen consumption, predisposes the pregnant patient to quicker desaturation and less tolerance for apnea [8].

During pregnancy, the effects of estrogen and increased blood volume can cause the airway to be edematous and friable. Capillary engorgement of the mucosa can cause edema of the pharynx, larynx, and trachea, which may necessitate a smaller size endotracheal tube [9]. If airway obstruction is present, nasopharyngeal airways should be used with caution due to the risk of bleeding. A short laryngoscope handle may be helpful to avoid abutting the larger breasts that frequently accompany pregnancy. The incidence of a difficult airway with pregnancy is significantly higher than in the general population [10, 11]. A "difficult airway cart" should be readily available, as well as providers who are trained in using adjunct airway equipment and advanced techniques [12•]. Additionally, for patients who have cervical spine trauma, fiberoptic intubation should be considered because of the desire to prevent worsening of neurologic injury in the setting of a higher incidence of difficulty with intubation [13]. Algorithms for difficult ventilation and intubation in obstetric anesthesia have previously been described [9].

Pregnant patients also have an increased risk for aspiration due to relaxation of the lower esophageal sphincter and displacement of the stomach cephalad by the gravid uterus. Progesterone also slows gastric emptying, and thus, pregnant women should be considered "full stomach" and should undergo a rapid sequence induction.

Evaluation and Resuscitation of the Pregnant Trauma Patient

The Eastern Association for Surgery and Trauma states "the best initial treatment for the fetus is the provision of optimum resuscitation of the mother and the early assessment of the fetus" [2]. Pregnant patients who are traumatically injured should be brought to the hospital and treated similarly to other patients. At term, the gravid uterus can weigh up to 5 kg; patients in the supine position can have a 30 % decrease in cardiac output, compromising blood flow to vital organs. All efforts should be made to displace the uterus off the inferior vena cava with a wedge or rolled up towels. Patients who are in C-spine precautions should not be moved, but a wedge can be placed under the backboard or providers can manually deflect the uterus to improve venous return.

The primary survey should be carried out expediently and should not differ from that of a non-pregnant patient. All pregnant women suffering from trauma should receive supplemental oxygen, as the fetus is sensitive to maternal hypoxia [14]. Uterine blood flow is directly related to maternal cardiac

Table 1 Key physiologic changes during pregnancy

Physiology	Change during pregnancy
Mean arterial pressure	Decreases by 5–15 mmHg
Cardiac output	Increases 30–50 %
Heart rate	Increases by 10–15 bpm
Hematocrit	Decreases due to more increase in blood volume than red blood cells, HCT 30–34 % at term
Tidal volume	Increases 40 %
Function residual capacity	Decreases 20 %
$PaCO_2$	Decreases to 27–32 mmHg
Gastrointestinal tract	Delayed emptying, decreased lower esophageal sphincter tone
Airway	Increased edema, difficult ventilation/intubation

output because uterine circulation is not autoregulated. Because systemic blood pressure is dependent on circulating intravascular volume and systemic vascular resistance, adequate volume replacement in the mother is necessary for sufficient uteroplacental blood flow. Patients who are >20 weeks pregnant should have a 50 % increase in the volume of fluids given their increase in plasma volume [14].

The success of maternal resuscitation is the greatest factor in determining fetal outcome. The average estimated blood loss for term vaginal delivery and C-section are 500 and 1000 mL, respectively. Due to the hypervolemic adaptations of pregnant women, this amount of hemorrhage may not result in a significant change in vital signs. Signs of maternal distress such as tachycardia and hypotension may not occur until hemorrhage of 1500–2000 mL [7]. Thus, the absence of maternal tachycardia or hypotension does not mean that significant hemorrhage has not occurred.

The secondary survey should include a complete history, including obstetrical history and evaluation of the fetus. The gestational age of the fetus should be determined, either from the patient's history, ultrasound, or measurement of the fundal height. Roughly, a fundal height at the umbilicus indicates a pregnancy of 20 weeks gestation. Neonatal specialists should be given advance warning if delivery of the fetus is a possibility. A vaginal examination should take place to look for blood or amniotic fluid. If vaginal bleeding is present and the patient is past the first trimester, placenta previa should be ruled out before cervical examination to look for dilation and effacement [14]. Fetal heart rate monitoring can be useful to guide fluid resuscitation because the fetal heart rate is sensitive to maternal hypovolemia. As part of the complete assessment, the Eastern Society for Surgery and Trauma has made Level II recommendations that fetal monitoring should be performed for all pregnancies at greater than 20 weeks gestational age for 6 h [2]. (See Table 2 for indications for fetal monitoring longer than 6 h.) Fetal monitoring will help assess fetal well-being but should not interfere with the care of the mother [1]. Laboratory analysis should include a Kleihauer–Betke test in all gravid patients more than 12 weeks gestational age [2]. Trauma care providers should also consider an obstetric consult.

The pregnant patient may need a trip to the operating room for surgical treatment of injuries sustained or to deliver the fetus. Ideally, an anesthesiologist familiar with trauma and obstetrical anesthesia should be available. Adequate venous access consisting of two large-bore intravenous lines should be attained for resuscitative measures. It should be noted that pregnancy decreases the amount of volatile anesthetic necessary during general anesthesia.

Even minor trauma can lead to injuries specific to pregnant patients that should be excluded during evaluation. The most concerning and leading cause of fetal death is placental abruption [5]. Risk factors for placental abruption include a positive Kleihauer–Betke test, frequent uterine contractions, vaginal bleeding, abdominal or uterine tenderness, postural hypotension, and fetal heart rate abnormalities [2, 3]. Other obstetric-related complications include preterm premature rupture of membranes, premature labor, premature delivery, uterine rupture, disseminated intravascular coagulation, fetal distress, fetal hypoxia, and fetal death [1••, 3–5]. Significant factors affecting fetal demise are younger gestational age and a higher injury severity to the mother [4, 5].

Amniotic fluid embolism is a rare event that can occur with trauma [15, 16]. The signs and symptoms are nonspecific and include fever, chills, nausea, headache, confusion, agitation, altered mental status, bronchospasm, hypoxia, cyanosis, pulmonary edema, cardiac arrhythmias, ventricular dysfunction, hypotension, coagulopathy from disseminated intravascular coagulation, seizures, fetal distress, and shock [15]. Supportive treatment of these signs and symptoms is the limit of current therapy [15, 16].

Cardiac Arrest in Pregnancy

Management of cardiac arrest in pregnant patients should follow standard advanced cardiac life support guidelines. Medications and their dosages should not be changed in pregnancy, and defibrillation should be performed at the usually recommended doses [17]. In cases of maternal cardiac arrest, a perimortem C-section may be performed. By definition, a perimortem C-section is one that occurs concurrent with maternal cardiopulmonary resuscitation [18, 19]. The physiological rationale for a perimortem C-section is that by delivering the fetus, venous return is improved and chest compressions will be more effective.

There are many reports of return of spontaneous circulation or improvement in maternal hemodynamic status occurring after delivery of the fetus [18, 19]. The American College of Obstetricians and Gynecologists recommends that the decision to perform a perimortem C-section should be made within 4 min of arrest, as outcomes correlate inversely with time from maternal arrest [18]. Other indications for emergency Cesarean delivery include a stable mother with a viable fetus in distress and traumatic uterine rupture [20].

Fetal Considerations

In the absence of clinical signs and symptoms of significant trauma, there is reluctance to obtain imaging, which causes ionizing radiation that can be harmful to the fetus [21•, 22]. Ultrasound by itself is not sensitive enough to rule out

Table 2 Reasons for continued fetal monitoring beyond 6 h [1••, 2, 32]

Mechanism includes
Ejection from a vehicle
Motorcycle crash
Pedestrian collision
Time between contractions is less than 10 min
Concerning signs on the fetal tracing (tachycardia, bradycardia, decelerations)
Maternal abdominal pain or discomfort
Vaginal bleeding
Rupture of amniotic membranes
Maternal heart rate greater than 110
Concern for maternal cardiopulmonary status
Glasgow Coma Score less than 10
Injury Severity Score greater than 9
Trauma requiring general anesthesia

injury, having a sensitivity of only 61–83 % [1••, 22, 23]. Ultrasound is also not sensitive enough to rule out placental abruption, and repeat ultrasounds days later may be necessary to detect placental abruption [1••, 3]. Although it is important to be judicious when using imaging associated with ionizing radiation during pregnancy, it is most important that the mother undergo imaging that is clinically indicated following a traumatic incident [2]. The typical imaging for trauma patients will result in less than half the 100 mGy threshold thought to cause growth retardation, intellectual deficiencies, and neural defects [24]. Although the increase in radiation exposure from a CT scan does place the fetus at a 0.2–0.8 % increased risk for developing cancer [5, 24], additional precautions can be taken to reduce the fetal exposure, including limiting the radiographic exposure, *z*-axis modulation, and changing the scan pitch [22]. Providers should consider discussing with a radiologist how to minimize exposure and consolidate studies if multiple scans are indicated based on the patient's injuries.

During surgery for the traumatically injured, the risks to the fetus can be placed in three categories: hypoxemia, teratogenic exposure, and preterm delivery [25]. The etiologies of hypoxemia include reduction of uterine blood flow, problems with maternal gas exchange, and depressants to the fetal cardiovascular, or nervous system [25]. Inhalational anesthetics have not been shown to be teratogenic in clinical concentrations. Commonly used anesthetic medications also do not seem to carry teratogenic potential, including benzodiazepines [5, 25]. Fetal heart rate monitoring should be considered for all surgeries where the surgical site allows for monitoring and the expertise is available for accurate interpretation [5]. An obstetrician should also be readily available, should an emergency C-section be necessary. When large hemodynamic changes are anticipated, fetal monitoring should be utilized to help assess the adequacy of placental perfusion. During an operation, administration of medications and hypothermia can cause loss of heart rate variability; however, decelerations should raise concern for possible fetal distress [25].

The Pregnant Burn Patient

About 7 % of women of childbearing age who have burn injuries are pregnant [26•]. Burns during pregnancy pose a major threat to the mother and fetus. In general, treatment is not changed significantly by pregnancy and specific guidelines for the management of pregnant burn patients are lacking. A pregnant patient with facial burn injuries is at high risk of airway compromise not only from the burn injury itself, but also from the pre-existing airway edema that accompanies pregnancy. Patients with signs of inhalational injury (hoarseness, stridor, soot in airway, singed nasal hairs) may require close vigilance and early tracheal intubation because post-injury edema may turn a previously uncomplicated airway into a complicated or difficult one.

Using the "rule of nines," the total body surface area (TBSA) burned can be estimated. Morbidity and mortality are correlated with the extent of the burn injury. In one series, both maternal and fetal mortality approached 100 % when TBSA >40 % [27]. Fluid resuscitation in burn patients is traditionally guided by the Parkland formula: TBSA (%) × 4 mL × wt (kg). However, pregnant burn patients have an increase in intravascular volume so that the Parkland formula can lead to under-resuscitation [28]. Thus, volume resuscitation should be guided by clinical signs such as maternal vital signs, urine output, and fetal heart rate and variability, rather than by formula alone.

Burn injury can cause the release of prostaglandins, which can cause preterm labor [14]. The risk of preterm labor increases as TBSA increases. The use of tocolytics may be indicated when TBSA is less than 30 % and gestational age is between 24 and 32 weeks, as long as fetal monitoring is reassuring [27]. Carbon monoxide (CO) poisoning can occur in the fetus because CO crosses the placenta and fetal hemoglobin has a higher affinity for CO. Detection must be with a co-oximeter, as a pulse oximeter will not detect CO poisoning. Treatment is with 100 % oxygen. Electrical burns during pregnancy are rare and the severity depends on the strength of the voltage exposure and the path of the current; fetal demise is common [29].

Neuroanesthesia in the Pregnant Patient

Nevelle et al. [30] have recommended that a multidisciplinary care team should be used to care for pregnant patients that sustain neurotrauma. Although there is a theoretical concern for dehydration in the fetus with the administration of mannitol, administering 100 g of mannitol, raising the maternal osmolarity to 320 mOsmol/kg, appears to be safe for the fetus [31]. Another concern is that hyperventilation, when used to reduce intracranial pressure, can reduce blood flow to the uterus [31].

Conclusion

Obstetric patients who experience even minor trauma are at a high risk of having a complication related to their pregnancy. This risk follows them even if they are rapidly stabilized, treated, and discharged without delivering their child during their hospitalization. Providers not only need to familiarize themselves with the physiologic changes that accompany pregnancy, but will need to adjust their management accordingly. The best outcomes occur when the team caring for the patient is adequately prepared and has the available resources to care for the injured pregnant patient.

Compliance with Ethics Guidelines

Conflict of Interest Tiffany Sun Moon and Joshua Sappenfield declare that they have no conflict of interest.

Human and Animal Rights and Informed Consent This article does not contain any studies with human or animal subjects performed by any of the authors.

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