Lesson 285: Cardiopulmonary Resuscitation During Pregnancy and Perimortem Cesarean Delivery

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Needs statement

The committee has identified the need for anesthesia practitioners to maintain skills involving extreme and emergent cases—including those involving cardiopulmonary resuscitation (CPR). One example of a rare, extreme case with anesthetic implications is emergency childbirth during maternal cardiac arrest.

Learning Objectives

At the end of this activity, the participant should be able to:

1. List the major causes of cardiopulmonary arrest during pregnancy.
2. Summarize maternal physiologic changes associated with pregnancy.
3. Discuss the effects of physiologic changes from pregnancy on maternal resuscitation.

4. Explain major differences in administering cardiopulmonary resuscitation between pregnant and non-pregnant patients.
5. Assess the indications for a perimortem cesarean delivery.
6. Discuss the beneficial effects of perimortem cesarean delivery on maternal resuscitation.
7. Recognize the most important predictor for fetal well-being after perimortem delivery.
8. Outline the clinical implications of lateral displacement of the uterus during maternal - resuscitation.
9. Describe the 4-minute rule for perimortem cesarean delivery.
10. Present a well-designed plan for resuscitation in the clinical scenario of maternal cardiac arrest.

Case History

A 40-year-old woman pregnant with twins at 29 weeks gestation, gravida V, para III, was admitted with shortness of breath and dyspnea on exertion. Her history was significant for long-standing smoking, moderate obesity, obstructive sleep apnea, and chronic hypertension that was controlled by labetalol. Initial measurements of her vital signs included blood pressure, 180/110 mm Hg; pulse, 96 beats per minute; respiration, 19 breaths per minute; and oxygen saturation, 93% on room air. A physical examination revealed rhonchi and rales bilaterally in lower lung bases and 2+ edema in the lower extremities. Laboratory test results were remarkable for 3+ proteinuria. Arterial blood gases on room air revealed pH 7.45; PaO_2 92 mm Hg; and $PaCO_2$ 33 mm Hg. Liver function tests and platelet counts were within normal ranges. An obstetric sonogram confirmed viable twins with fetal heart rates of 130 to 140 beats per minute.

The patient was diagnosed with chronic hypertension with superimposed preeclampsia. Initial management included supplemental oxygen, IV labetalol, and magnesium sulfate. A chest x-ray and chest computed tomography (CT) angiography were scheduled to rule out pulmonary embolism.

Approximately 2 hours after her arrival, the patient became acutely anxious, tachypneic, and cyanotic. Oxygen saturation was determined to be 80% with a non–rebreather mask. Within minutes, the patient underwent respiratory arrest and was found to have no pulse. A cardiac arrest code was activated.

The true incidence of cardiac arrest during pregnancy is unknown but has been estimated at 1 in 30,000 pregnancies.[1]

Etiology

In the United States, the major causes of cardiac arrest during pregnancy include, in order of decreasing frequency, venous thromboembolism, severe pregnancy-induced hypertension (preeclampsia and eclampsia), sepsis, amniotic fluid embolism, hemorrhage, trauma, iatrogenic causes (including complications of anesthesia, drug errors, allergies), and congenital and acquired heart disease. An important contributor to cardiac arrest during pregnancy is the increasing average age of pregnant women in the United States, which increases the prevalence of comorbidities.

Over the last century, causes of maternal mortality have shifted from primarily chronic and mostly infectious to primarily acute and mostly cardiopulmonary. An infant delivered by perimortem cesarean

from a mother with chronic disease has a decreased chance of survival compared with the infant whose previously healthy mother undergoes cardiac arrest caused by an acute event such as pulmonary embolus.

Historical Background

Cesarean delivery, one of the oldest surgical procedures, can be traced back to at least 800 BC. Prior to the 20th century, the phrase postmortem cesarean was redundant because the procedure was not undertaken unless the mother was dead or moribund. Initially, the Romans had decreed that unborn infants should be excised from the womb if the mother had died late in pregnancy; the purpose was religious ritual rather than an attempt at saving the newborn.[2] However, some infants did survive and several ancient historical figures were reported to have been born in this fashion, including the Greek physician Asklepios, "from the womb of dead Koronis."[3]
During the late 19th and early 20th centuries, case reports began to appear of postmortem cesarean deliveries in which the fetus was rescued, and the procedure began to be considered as a legitimate medical intervention.[2] However, the survival rate was very low and therefore conventional wisdom dictated that all possible attempts be made to resuscitate the mother.

During the early 1980s, several authors reported unexpected maternal recovery after postmortem cesarean delivery.[4,5] An immediate restoration of maternal circulation after emergency cesarean delivery was demonstrated in a pregnant patient undergoing cardiac arrest.[4] In 1982, Marx[5] suggested that prolonged cardiopulmonary resuscitation (CPR) without prompt cesarean delivery in patients with cardiac arrest was associated with worsened maternal outcome; this led to consideration of the possibility that immediate cesarean delivery during maternal cardiac arrest might improve a parturient's chance of survival.

The term *perimortem cesarean section* was introduced in 1986 to describe the procedure of cesarean delivery concurrent with maternal CPR.[6] The procedure is recommended in patients undergoing cardiac arrest who do not respond to aggressive resuscitation and in whom gestation is estimated to be more than 24 weeks. Cardiac resuscitation in late pregnancy is relatively ineffective due to aortocaval compression by the gravid uterus. Evacuation of the uterus by delivering the baby may not only ensure better survival of the infant, but also may optimize the effectiveness of maternal resuscitation.

Physiologic Changes During Pregnancy: Effects on Maternal Resuscitation

Cardiovascular changes that normally occur during pregnancy are important considerations in maternal resuscitation efforts. Cardiac output increases by 30% to 50%, reaching its peak at about 32 weeks gestation. This increase is caused by increases in heart rate and stroke volume, together with a decrease in systemic vascular resistance. Aortocaval compression by the gravid uterus occurs at approximately 20 weeks of gestation and is responsible for "supine hypotension syndrome," reflecting a decrease in cardiac output by as much as 25%.[7]

The implications of managing CPR associated with pregnancy are significant. Chest compressions in a nonpregnant individual produce approximately 30% of normal cardiac output, but only 10% in the later stages of pregnancy. In addition, the gravid uterus receives up to 30% of cardiac output as the result of markedly increased uteroplacental blood flow, compared with the non-gravid uterus, which receives less than 2% of cardiac output. Thus, the effectiveness of chest compressions may be attenuated by

the obstructive effect of the gravid uterus on the great vessels together with the shunting of a large percentage of blood flow to the gravid uterus.

Maternal blood volume increases as early as the seventh week of gestation, reaching a plateau at 34 weeks. Red cell mass also increases, but relatively less than the increase in plasma volume; this results in a decrease in hematocrit and the physiologic anemia of pregnancy. During maternal cardiac arrest, anemia may have an impact on oxygen delivery to vital organs such as the heart, brain, and fetus.

Resting oxygen consumption increases during pregnancy, whereas functional residual capacity and residual volume are reduced secondary to diaphragmatic elevation by the gravid uterus and enlarged breasts. The combination of these changes can lead to a rapid decline in oxygen saturation during apnea.

The pregnancy-associated increase in levels of progesterone relaxes sphincter tone of the lower esophagus. During labor, gastric emptying is delayed, increasing the risk for aspiration during mask ventilation and intubation. Edema of the upper airway, increased breast size, and generalized weight gain can interfere with adequate ventilation and intubation during maternal resuscitation.

CPR During Maternal Cardiac Arrest

Cardiac arrest in a pregnant patient is an infrequent event that an anesthesia provider encounters rarely. Although maternal CPR may be impeded by the physiologic changes of pregnancy, in general resuscitation algorithms are the same as for nonpregnant patients—with some exceptions (Figure).[8]

Cardiac compression in the pregnant woman is inefficient because of the compression of the great vessels by the gravid uterus and resultant decreases in venous return and cardiac output. Therefore, lateral tilting should be the first maneuver in the event of maternal cardiac arrest. Manual displacement of the uterus, placement of a wedge under the right hip, or use of a Cardiff resuscitation wedge all are acceptable methods. Effective forces for chest compression can be generated with the patient inclined at an angle up to 30 degrees; pregnant women tend to roll into a full lateral position when inclined at an angle exceeding 30 degrees. The Cardiff resuscitation wedge, a wooden frame inclined at a 27-degree angle, is specially designed for performing CPR during pregnancy. Alternatively, the “human wedge” technique can be used to tilt the patient on a rescuer’s knees to provide a stable tilted position.

Hypoxia develops much more rapidly during hypoventilation because of increased oxygen consumption and decreased functional residual capacity in pregnancy. Also, pregnant patients are at increased risk for aspiration, which may be exacerbated by gastric distention from air insufflation during bag-mask ventilation. Therefore, rapid control of the airway by endotracheal intubation is imperative during maternal resuscitation.

Although controversial, the application of continuous cricoid pressure during bag-mask ventilation and endotracheal intubation is still considered the standard of care. The use of a smaller than expected endotracheal tube is recommended because of the potential for airway edema associated with pregnancy.

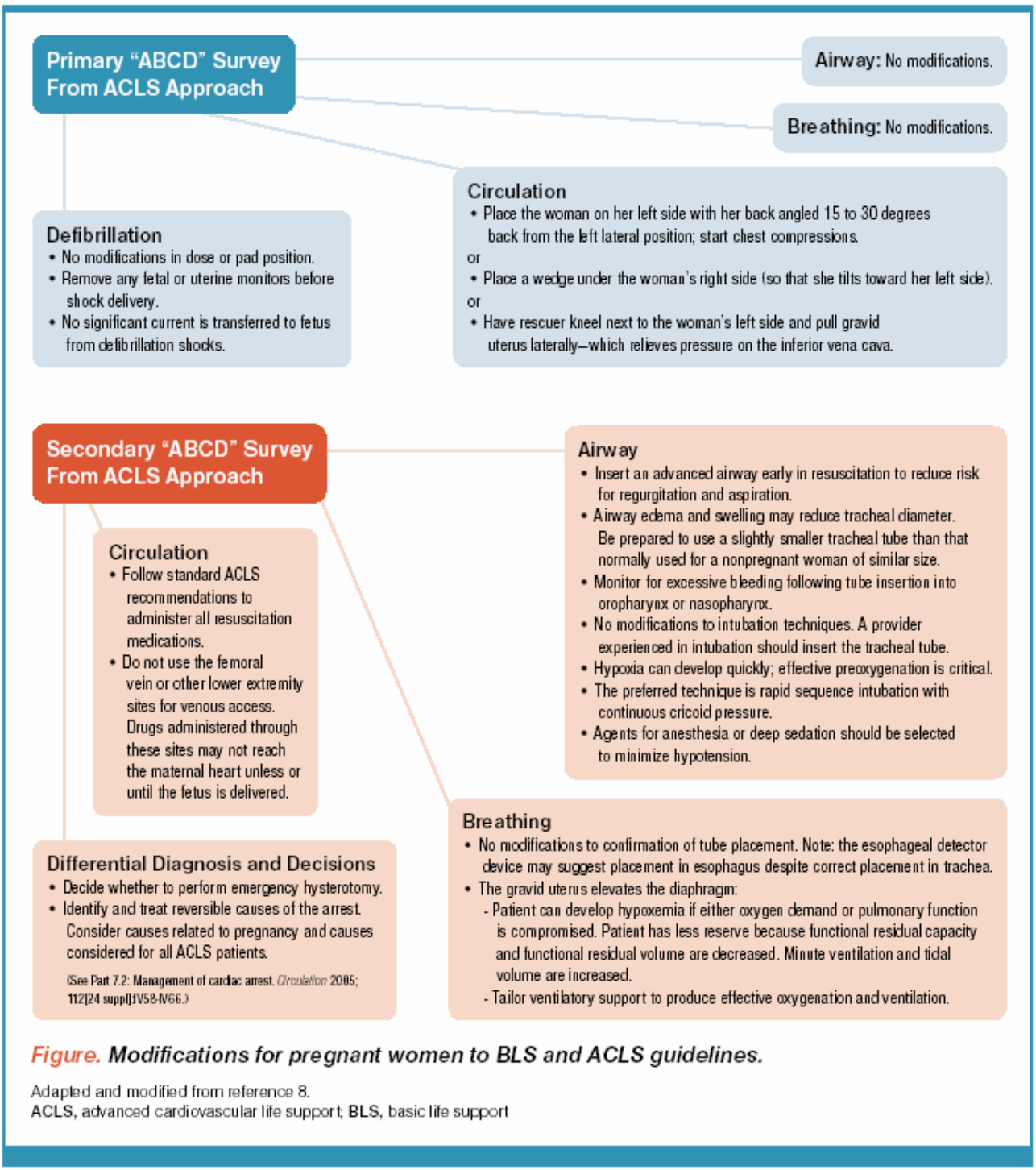

Figure. Modifications for pregnant women to BLS and ACLS guidelines.

Adapted and modified from reference 8.
ACLS, advanced cardiovascular life support; BLS, basic life support

Available evidence suggests that defibrillation energy requirements do not change significantly with pregnancy[9]; thus, positioning and dosing do not need to be modified for cardiac defibrillation. Defibrillation does not carry any increased risk for the fetus, but the fetal monitor should be removed prior to defibrillation.[8] The same protocols for pharmacologic management of CPR should be used for pregnant and nonpregnant patients. Scant information is available regarding the potential impact of resuscitation drugs on the fetus; however, the vasoconstrictive effects of high doses of α-adrenergic agents on uteroplacental circulation have been demonstrated in animal studies.[10] Use of these drugs in resuscitation is essential because rapid restoration of maternal circulation offers the best chance for survival for both mother and fetus.

Because the enlarging uterus compresses the pelvic veins, IV lines in the lower extremities should be avoided, if possible. When IV access below the uterus is unavoidable, medication administered by that route has a limited return to the heart and the arterial circulation of the mother.[8]

Perimortem Cesarean Delivery

Indications

The major indication for perimortem cesarean delivery is to optimize maternal CPR. Fetal survival is secondary, even at a viable gestational age. Infants born earlier than 24 weeks of gestation are not likely to survive, and among those surviving, the likelihood of normal neurologic function is extremely low.

The gravid uterus progressively reaches a size that may affect aortocaval blood flow, starting at approximately 20 weeks of gestation. However, with a significantly smaller fetal-placental mass, aortocaval compression by the gravid uterus is less pronounced if gestational age is less than 24 weeks. Delivery may not achieve as dramatic an improvement in hemodynamics, as it would at a later gestational age.

Although the American Heart Association (AHA) guidelines state, "emptying the uterus by perimortem cesarean section at 20 to 23 weeks of gestation may enable successful resuscitation of the mother,"[8] limited data are available to support that premise. It is still uncertain whether cesarean delivery of a pre-viable fetus (<24 weeks) is beneficial to maternal outcome. After 24 weeks of gestation, cesarean delivery not only optimizes maternal survival by relieving aortocaval compression, but also allows an attempt at resuscitation of the infant.

In cases when gestational age is less than 20 weeks, the objectives of resuscitation can be directed almost exclusively to maternal considerations to provide the best hope for recovery of both mother and fetus. In 1988, Selden and Burke reported the case of successful resuscitation of a woman with cardiac arrest at 15 weeks gestation. Spontaneous circulation returned after a prolonged period of CPR with subsequent continuation of the pregnancy to term, and a favorable neurologic outcome for both mother and baby.[11]

Prognosis

Emergency cesarean delivery should be considered if gestational age is at least 24 weeks and initial resuscitation efforts are unsuccessful. The single most important determinant for the prognosis of fetal well-being following perimortem cesarean delivery is the time elapsed from maternal cardiac arrest to cesarean delivery.

Outcomes for infant survival and neurologic status appear to be the best when delivery is within 5 minutes of maternal cardiac arrest.[6] Fetal survival declines significantly thereafter, along with the likelihood of normal neurologic function. Perimortem cesarean delivery should be initiated within 4 minutes of maternal arrest if circulation has not been restored with CPR, and accomplished within 5 minutes.[6] These recommendations have been adopted by the AHA.[8] Whereas delivery within the above time frame results in the highest percentage of normal infants, there also have been numerous

reports of neonatal survival without adverse neurologic sequelae when delivery occurred more than 5 minutes after cardiac arrest.[4,12] In 2002, Finegold et al[12] reported the case of a full-term parturient who underwent cardiac arrest caused by an amniotic fluid embolism. An emergency cesarean delivery was performed 15 minutes after arrest, and both mother and infant survived without neurologic complications. Less recently, DePace et al[4] described the successful resuscitation of mother and infant after 25 minutes of CPR. Although such case reports suggest that the 4-minute rule should not be taken as absolute, it is recommended that a cesarean delivery is immediate for a potentially viable fetus, when attempts at maternal resuscitation fail.

No data suggest that perimortem cesarean deliveries are associated with a lower rate of maternal recovery. Most reports, including the case presented here, suggest that evacuation of the fetus helps restore maternal circulation.[4,12] Indeed, a cesarean delivery is recommended by the AHA for maternal reasons[8]: "Emptying the uterus for persistent cardiac arrest in the mother offers the best hope for a positive outcome for both the mother and the fetus."

It is likely that the beneficial effect is multifactorial; relief of compression on the inferior vena cava increases cardiac output as the result of greater venous return and autotransfusion from contraction of the uterus. Decreased shunting of blood to the uteroplacental circulation further contributes to increased cardiac output; functional residual capacity also is improved, and maternal metabolic demand decreased, thus increasing oxygenation.

To maximize cardiac output and uteroplacental perfusion, cardiac resuscitation measures should be applied while preparing for surgery, and continued during surgery. Documenting the fetal heart rate is not required before the perimortem cesarean delivery because the time required for it would be detrimental. In 1965, Miller et al described the delivery of a viable infant in the absence of fetal heart sounds.[13]

A coordinated team approach is essential for successful resuscitation of a parturient undergoing cardiac arrest; timing is of the essence. The most experienced obstetrician available should be consulted. Adequate neonatal resuscitation equipment and a neonatologist should be available. Delivery should take place without relocating the mother because time does not allow for the patient's transfer to the operating room. Sterile technique should be maintained to the maximum extent possible. Prophylactic broad-spectrum antibiosis should be instituted.

Medicolegal Considerations

No physician has been found liable for performing a perimortem cesarean delivery, even when done without the family's consent.[6] In fact, there was one recorded instance of the death penalty applied to a physician in the 18th century for failure to perform the procedure.[2] Currently in at least one state (Oklahoma), regulations specifically allow the procedure. However, in today's litigious society, medical liability is a legitimate concern; obtaining informed consent from next of kin is desirable, if possible. Inability to obtain informed consent should not delay a potentially lifesaving procedure. Most experts agree that, in the setting of maternal cardiac arrest, the doctrine of emergency or implied consent applies, with the rights of the (unborn) child being first and foremost.[14,15]

A patient has the right to refuse a cesarean delivery based on the principle of maternal autonomy, even if her baby is in extreme jeopardy. However, when maternal consent is not possible, no other opinion should be deemed as legally binding in an emergency. Consensus in the medical literature and

among legal authorities is that a civil suit against a physician for performing a perimortem cesarean delivery—regardless of the outcome—would not result in a judgment against the physician.[3,6,14,15]

Management of the Case Presented

CPR was initiated and a wedge placed under the patient's right hip. The patient was intubated immediately, with correct placement confirmed by capnography and the presence of bilateral breath sounds. No muscle relaxant or anesthetics were administered for intubation.

An electrocardiogram revealed sinus bradycardia (25-35 beats/min) which progressed to asystole. A total of 1 mg atropine and 2 doses of epinephrine (1 mg each) were given intravenously. Sinus rhythm returned at a rate of 80 to 90 beats per minute, but no pulse was palpable.

An emergency cesarean delivery was ordered and performed at the bedside by the obstetric team 7 minutes after maternal arrest. CPR was ongoing during surgery. Twins were delivered at 9 and 10 minutes after maternal arrest. Twin A weighed 1,380 g; Apgar scores were 1 (at 1 min) and 8 (at 5 min). Twin B weighed 935 g; Apgar scores were 4, 7, and 9 (at 1, 5, and 10 min, respectively).

Both infants developed respiratory distress syndrome and were transferred to the neonatal intensive care unit and intubated. Immediately after delivery of the twins, the mother's pulse returned; transient supraventricular tachycardia and blood pressure of 220/138 mm Hg were noted. Chest compressions were discontinued. Heart rate and blood pressure gradually returned to normal ranges in approximately 5 minutes.

Approximately 15 minutes after delivery of the twins, the mother regained consciousness and was appropriately responsive prior to completion of the surgery. Therefore, IV midazolam (4 mg) and fentanyl (200 mcg) were administered in divided doses for amnesia and analgesia, respectively. Oxytocin, cefazolin, and vancomycin were administered intravenously immediately after delivery.

After resuscitation of the patient, measurement of arterial blood gases on 100% fraction of inspired oxygen determined: pH 7.04; $PaCO_2$ 49 mm Hg; PaO_2 420 mm Hg; bicarbonate 13.2; and base excess –16.9. IV sodium bicarbonate (100 mEq) was administered.

Emergency echocardiography was conducted at the mother's bedside; findings included an ejection fraction of 40%, and a normal right ventricle. A radial artery catheter and a right subclavian double-lumen venous catheter were placed. Blood pressure and central venous pressure were 140/84 and 12 mm Hg, respectively. The patient—on oxygen and with hemodynamic monitoring—was transferred to the intensive care unit. Postoperatively, she did not require hemodynamic support and was extubated the next day without neurologic sequelae. Her recall of the perioperative events was limited to the moment after she regained consciousness prior to the administration of midazolam.

Postoperatively, a chest x-ray and computed tomography (CT) angiography revealed pulmonary edema and left lower lobe pulmonary embolus. Preeclampsia, pulmonary embolism, peripartum cardiomyopathy, and congestive heart failure were diagnosed. She was treated with IV heparin, magnesium sulfate, antihypertensives, and diuretics. Eventually, an inferior vena cava filter was placed. The patient's postoperative course was remarkable for pelvic hematoma, which was drained by interventional radiology. She was discharged home on postoperative day 14 in stable condition.

Because of prematurity, the twins required an extended stay in the hospital. Both received phototherapy for hyperbilirubinemia. Twin A experienced a grade III intraventricular hemorrhage and was discharged home at 81 days old. A CT scan of the head prior to discharge showed near complete resolution of the intraventricular hemorrhage. Twin B had 2 suspected seizures; however, electroencephalographic, head CT, and magnetic resonance imaging results were unremarkable. Twin B was discharged home at 70 days old. Ten months later, the infants were doing well, although formal developmental testing remained to be performed.

Conclusion

CPR in the patient with cardiac arrest should be performed with consideration of the physiologic changes associated with pregnancy. Standard algorithms should be applied according to advanced cardiac life support protocols, with few exceptions. Attention to lateral displacement of the uterus, more aggressive airway management, and early consideration of emergency cesarean delivery are major modifications in the management of maternal arrest. Cesarean delivery should be performed as soon as possible if gestational age is at least 24 weeks, and initial maternal resuscitation is unsuccessful. The best predictor of fetal survival when a parturient suffers cardiac arrest is the time between maternal arrest and fetal delivery. Immediate cesarean delivery not only improves survival of the infant but also facilitates maternal resuscitation.

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Post-test

1. The most common cause of maternal cardiac arrest in the United States is:

a. trauma
b. congenital heart disease
c. venous thromboembolism
d. sepsis

2. The incidence of cardiac arrest during pregnancy is:

a. variable depending on maternal age
b. estimated at 1 in 10,000
c. estimated at 1 in 30,000
d. unknown

3. Approximately when does aortocaval compression by the gravid uterus become clinically significant?

a. It is never a factor
b. At 10 weeks gestation
c. Only at term
d. At 20 weeks gestation

4. Rapid oxygen desaturation during apnea in pregnant women is caused by all of the following, except:

a. an increase in resting oxygen consumption
b. a decrease in functional residual capacity
c. a decrease in cardiac output
d. a decrease in lung residual volume

5. Which of the following is the first resuscitation maneuver in the event of maternal cardiac arrest?

a. Endotracheal intubation
b. Administration of IV epinephrine
c. Relieving aortocaval compression by lateral tilting of the patient
d. Checking fetal heart rate

6. Acceptable approaches to relieve aortocaval compression during maternal cardiac arrest include all of the following, except:

a. manual displacement of the uterus
b. placing a wedge under the patient's right hip
c. placing the patient in the head-up position
d. placing a Cardiff resuscitation wedge under the patient

7. The current recommendation for defibrillation energy requirements during maternal cardiac resuscitation include:

a. applying the same defibrillation energy as in the nonpregnant patient
b. reducing defibrillation energy in the pregnant patient
c. changing the energy levels depending on the stage of pregnancy
d. increasing energy levels at all stages of pregnancy

8. The single most important determinant of fetal wellbeing following perimortem cesarean delivery is:

a. fetal body weight
b. the cause of maternal cardiac arrest
c. the time elapsed from maternal arrest to fetal delivery
d. age of the mother

9. Evacuation of the uterus by delivering the fetus facilitates maternal resuscitation by all of the following mechanisms, except:

a. an increase in cardiac output by elimination of aortocaval compression
b. an increase in cardiac output by "autotransfusion" from uterine contraction
c. an increase in functional residual capacity
d. a decrease in defibrillation energy requirement and thus the heart converts more easily to normal rhythm

10. An ideal location to perform perimortem cesarean delivery is:

a. obstetric operating room
b. main operating room
c. labor and delivery room
d. in the location where maternal cardiac arrest occurs