Cardiopulmonary arrest in pregnancy

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INTRODUCTION — Cardiopulmonary arrest during pregnancy presents a unique clinical scenario involving two patients: the mother and the fetus. Management of these patients demands a rapid multidisciplinary approach, including anesthesiology, medicine, obstetrics, neonatology, and sometimes cardiothoracic surgery [1]. Basic and advanced cardiac life support algorithms should be implemented; however, the physiological and anatomical changes of pregnancy require some modifications to these protocols. Randomized trials of approaches to management of pregnant women with cardiopulmonary arrest are lacking; therefore, recommendations for these modifications are based on data from small case series and small cohort studies involving patients with cardiac arrest during cesarean delivery, and expert opinion.

This topic will focus on management of cardiopulmonary arrest during pregnancy. Management of cardiac arrest in nonpregnant populations is reviewed separately:

- (See "Overview of sudden cardiac arrest and sudden cardiac death".)
- (See "Supportive data for advanced cardiac life support in adults with sudden cardiac arrest".)
- (See "Advanced cardiac life support (ACLS) in adults".)
- (See "Pathophysiology and etiology of sudden cardiac arrest".)
- (See "Therapies of uncertain benefit in basic and advanced cardiac life support".)
- (See "Sudden cardiac arrest in the absence of apparent structural heart disease".)

PREVALENCE — The prevalence of cardiac arrest in pregnant women varies from 1/20,000 to 1/50,000 ongoing pregnancies [2-4]. In the United States, data from the National Inpatient Sample (NIS) indicated that cardiac arrest complicated approximately 1 in 12,000 hospitalizations for delivery between 1998 and 2011, and the frequency remained stable over the interval [5]. Data for Canada between 2002 and 2015 was similar, cardiac arrest occurred in 1 in 12,500 deliveries [6].

ETIOLOGY — Cardiac arrest may be related to conditions unique to pregnancy or etiologies found in the nongravid state (table 1). Frequencies by etiology are illustrated in the following large studies:

- A review of the most common causes in pregnant women in the United States and United Kingdom reported: pulmonary embolism (29 percent), hemorrhage (17 percent), sepsis (13 percent), peripartum cardiomyopathy (8 percent), stroke (5 percent), preeclampsia-eclampsia (2.8 percent), and complications related to anesthesia (eg, difficult or failed intubation, local anesthetic toxicity, aspiration, high neuraxial block) (2 percent) [7]. Amniotic fluid embolism, myocardial infarction, pre-existing cardiac disease (congenital, acquired, cardiomyopathy), and trauma were additional major causes of cardiac arrest, but the frequencies were not reported.

- In the United States Nationwide Inpatient Sample 1998 to 2011, the distribution of maternal cardiac arrests (n = 4843) is shown in the table (table 2).

Smaller series have reported additional findings. In a series of 80 pregnant/postpartum women in the United Kingdom with sudden unexpected death due to cardiac causes, the leading causes were sudden arrhythmic death syndrome (54 percent), cardiomyopathy (14 percent), dissection of aorta or its branches (9 percent), congenital heart disease (2.5 percent), and valvular disease (4 percent [8]). Nearly 60 percent of patients were obese or overweight. In a series of 66 cardiac arrests identified through the United Kingdom Obstetric Surveillance System, 16 arrests were attributed solely as a consequence of obstetric anesthesia; 12 of these women were obese [9]. High neuraxial anesthesia accounted for 13 of the 16 cases. All of the women with arrests as a result of anesthesia survived due to immediate resuscitation, including peripartum cesarean delivery.

The following A through H mnemonic was devised by the American Heart Association to help providers remember causes of cardiac arrest that should be considered in pregnant women [10]:

- A: Anesthetic complications, Accident/trauma
- B: Bleeding
- C: Cardiac
- D: Drugs
- E: Embolic causes
- F: Fever
- G: General including hypoxia, electrolyte disturbances
- H: Hypertension

KEY PRINCIPLES FOR RESUSCITATION — Resuscitation of the pregnant woman involves simultaneous, rather than sequential, maneuvers and interventions:

- Call a maternal code blue, which should include a multi-disciplinary team (adult resuscitation, obstetrics, anesthesia, neonatology, medicine).
- If the uterus is at or above the umbilicus, manually displace the uterus laterally and to the left (ie, left uterine displacement) (See 'Avoiding aortocaval compression' below.)
- Initiate chest compression and ventilation using standard hand placement for chest compression [11]. (See "Basic life support (BLS) in adults", section on 'Performance of excellent chest compressions' and "Basic life support (BLS) in adults", section on 'Ventilations'.)

  Do not delay usual measures such as defibrillation and administration of medications. (See "Basic life support (BLS) in adults", section on 'Defibrillation' and "Advanced cardiac life support (ACLS) in adults".)

  Place intravenous access above the diaphragm.

  Assume the patient has a difficult airway. (See "Airway management of the pregnant patient at delivery".)
- Estimate the gestational age of the fetus. (See 'Determining gestational age' below.)
- When arrest persists, perimortem delivery by cesarean (also called resuscitative hysterotomy [12]) must be initiated at four minutes postarrest, and preparation should begin for this at the moment the obstetrical team arrives. A dedicated timer should alert the entire resuscitative team when four minutes after the onset of a maternal cardiac arrest have elapsed.

- If there is no return of spontaneous circulation with the usual resuscitation measures and the uterine fundus is at or above the umbilicus, at four minutes begin perimortem cesarean and complete delivery of the newborn by five minutes following cardiac arrest. In pregnant women, delivery early in the resuscitation process is a key intervention for improving success rates. (Perimortem cesarean delivery can be defined as a cesarean delivery after cardiopulmonary resuscitation has been initiated [3]). (See 'Delivery as part of the resuscitation process' below.)

- After 15 minutes of unsuccessful resuscitation, initiate direct cardiac massage if appropriate resources and personnel are available [13,14]. Thoracotomy and open chest message are particularly effective for patients with chest trauma, tension pneumothorax, massive pulmonary embolism, pericardial tamponade, and chest or spine deformities. Thoracotomy may also facilitate treatment of the underlying cause of the arrest (eg, removal of pericardial fluid/thrombus in cardiac arrest due to pericardial tamponade). (See 'Additional interventions' below.)

- Evaluate need to institute cardiopulmonary bypass [13]. (See 'Additional interventions' below.)

- Continue resuscitation measures until all resources and attempts have been exhausted. This will vary depending upon the clinical circumstances and resources of the facility. (See "Advanced cardiac life support (ACLS) in adults", section on 'Termination of resuscitative efforts'.)

Simultaneously, factors causing or contributing to cardiac arrest should be treated promptly (eg, bleeding/disseminated intravascular coagulation, electrolyte abnormalities, tamponade, hypothermia, hypovolemia, hypoxia, hypermagnesemia, myocardial infarction, poisoning, embolism [pulmonary, amniotic fluid, coronary], tension pneumothorax, anesthesia complications, aortic dissection). Treatment of these disorders is reviewed in separate topics.

MANAGEMENT OF RESUSCITATION — The sequence of resuscitation is well-described (see "Advanced cardiac life support (ACLS) in adults"). In pregnant women with uterine fundal height at or above the umbilicus, the uterus should be displaced to the patient's left during resuscitation to minimize aortocaval compression [15] (see 'Avoiding aortocaval compression' below).

Airway management — Active airway management is the initial consideration. Key points are:

- Oxygenate well with 100 percent oxygen by face mask to avoid desaturation (8 to 10 breaths/min)

- Avoid nonphysiologic respiratory alkalosis (normal pregnancy is associated with mild respiratory alkalosis)

- Ventilation volumes may need to be lower than in nonpregnant women if the uterus is very large

Pregnant women are at increased risk of rapidly developing hypoxemia because of decreased functional residual capacity and increased oxygen consumption, as well as increased intrapulmonary shunting [16-20]. Both intubation and bag mask ventilation can be more difficult in the late stages of pregnancy and back-up airway procedures, including cricothyrotomy, may be required in some cases. During pregnancy, the elevated diaphragm may result in the need for lower ventilation volumes and increased resistance to ventilation. (See "Airway management of the pregnant patient at delivery".)

The increased risk of aspiration and narrowing of upper airways, particularly in the third trimester, require special consideration during pregnancy. Bag-mask ventilation with 100 percent oxygen (two-handed, >15 L/min) and suctioning of the airway are critical to perform before intubation in a pregnant woman. Intubation via direct or video laryngoscopy and 100 percent oxygen is performed using a smaller-sized endotracheal tube (0.5 mm to 1.0 mm less in internal diameter compared to that used for nonpregnant women). Endotracheal tube placement should be verified using capnography. Cricoid pressure during laryngoscopy, once universally recommended, is now controversial because of lack of evidence of benefit and its ability to make both intubation and placement of a supraglottic airway more difficult. If used, pressure must be applied correctly over the cricoid cartilage, and the operator should discontinue it in cases where laryngoscopic view of the glottis is inadequate (see "Carbon dioxide monitoring (capnography)"). Supraglottic airway devices such as the laryngeal mask airway should be considered if unable to intubate [21]. No more than two attempts with either direct laryngoscopy or videolaryngoscopy before insertion of a supraglottic device are recommended [10].

Hyperventilation has adverse effects and should be avoided in any patient undergoing resuscitation. In pregnancy, maternal alkalosis can cause uterine vasoconstriction, which can lead to fetal hypoxia and acidosis [22]. (See "Advanced cardiac life support (ACLS) in adults", section on 'Airway management while performing ACLS'.)

Chest compressions — High-quality chest compressions are the cornerstone of the resuscitation process. The 2015 American Heart Association guideline on cardiac arrest in pregnancy recommends the same hand position for and performance of chest compressions in pregnant women and nonpregnant adults because of an absence of data supporting a different approach in pregnancy [10]. Previous guidelines suggested a more cephalad hand position in pregnancy to adjust for elevation of the diaphragm by the gravid uterus: However, an imaging study showed no significant vertical displacement of the heart in the third trimester of pregnancy relative to the nonpregnant state [11] (see "Basic life support (BLS) in adults", section on 'Performance of excellent chest compressions').

Intravenous access — Intravenous access should be established above the femoral region since drugs administered via the femoral vein may not reach the maternal heart until the fetus is delivered. Access to an antecubital vein with two 14-gauge catheters can be as effective as central line catheters for volume replacement, but do not allow hemodynamic monitoring [13]. In the absence of intravenous access, rapid intraosseous access can be achieved in a few seconds using commercially available kits. If neither intravenous nor intraosseous access is possible, the endotracheal tube can be used to administer certain medications including lidocaine, atropine, naloxone, and epinephrine. (See "Advanced cardiac life support (ACLS) in adults", section on 'Management of specific arrhythmias'.)

Avoiding aortocaval compression — We suggest manual uterine displacement to avoid aortocaval compression and preserve supine positioning of the upper torso for optimal chest compression vector forces. A hand is used to apply maximal leftward push to the right upper border of the uterus to achieve displacement of about 1.5 inches from the midline [23].

Left lateral uterine displacement is necessary in the pregnant patient with fundal height at, or above, the umbilicus, to minimize aortocaval compression (supine hypotensive syndrome), optimize venous return (preload), and generate adequate stroke volume during cardiopulmonary resuscitation (CPR). Our preference for manual uterine displacement is based on a randomized trial that compared manual uterine displacement versus operating room table tilt during cesarean delivery and demonstrated significantly fewer episodes of hypotension and a lower ephedrine requirement in the manual displacement group [23]. In addition, manual displacement of the uterus allows the patient's upper torso to remain supine, which enables application of maximum resuscitative force for effective chest compressions, improves airway and intravenous access, and improves access for defibrillation.

Other methods to achieve left lateral uterine displacement include: tilt of the operating room table or placement of pillows, a wood or foam resuscitation wedge (eg, Cardiff wedge), or rolled up towels or blankets under the patient [24]. If a suitable wedge is not available, the patient can be tilted upon a rescuer (the rescuer sits on his/her heels and uses his/her thighs as a wedge under the patient) [25]. If the patient is tilted, an angle of no more than 30 degrees is probably optimal. A study that used a calibrated force transducer to assess the maximum chest compression force generated at various angles of inclination in late pregnancy found that maximum resuscitative force (expressed as percent body weight) decreased from 67 percent in the supine position to 36 percent in the full lateral position [24]. Optimal compressive force was achieved at an angle of 27 degrees and was 57 percent (80 percent of the force generated in the supine position).

Defibrillation — Management of ventricular arrhythmias may require defibrillation during maternal resuscitation. The physiological changes of pregnancy, including increases in blood volume and decreases in functional residual capacity, do not appear to alter transthoracic impedance or transmyocardial current [26]. Therefore, current energy requirements for adult defibrillation are appropriate for use in pregnant women (biphasic shock 120 to 200 Joules with subsequent increase in energy output if the first shock is ineffective) [10]. Before delivering the countershock, remove fetal monitoring equipment to prevent electrocution injury to the patient or rescuers. This risk is theoretical and of greatest concern when the fetus has scalp electrodes. (See "Basic principles and technique of external electrical cardioversion and defibrillation".)

Determining gestational age — In pregnant women, determining gestational age is critical, as the likelihood of neonatal viability is a factor in decision-making. If the prenatal record or a corroborating family member is not available, physical examination can aid in establishing the gestational age. Uterine size correlates with gestational age, but can be misleading in some situations, such as when there is a multiple gestation, large fibroids, severe oligohydramnios or polyhydramnios, or maternal obesity. The formula for estimating gestational age by physical examination is: distance from the top of the symphysis pubis to the top of the fundus (cm) = gestational age (weeks). The top of the uterine fundus is generally at the level of the umbilicus by 20 weeks of gestation in a singleton pregnancy. Ultrasound is a reliable method for gestational age assessment, but may not be possible due to time and logistical constraints during maternal assessment and resuscitation. (See "Prenatal assessment of gestational age, date of delivery, and fetal weight" and "Incidence and mortality of the preterm infant" and "Periviable birth (Limit of viability)".)

Fetal monitoring — In general, the status of the mother should guide management during the resuscitation process; if the status of the mother is poor and deteriorating, the status of the fetus will be further compromised. Therefore, fetal monitoring is not recommended during the resuscitation process. If CPR is successful and the mother becomes hemodynamically stable, fetal monitors can be applied to assess the status of the fetus that is at a potentially viable gestational age. Intervention (in utero resuscitation measures, delivery) for nonreassuring fetal status depends on maternal- and fetal-specific factors.

Delivery as part of the resuscitation process — The American Heart Association and others recommend cesarean delivery if spontaneous circulation has not returned within four minutes of maternal cardiorespiratory collapse [10,27,28]. Ideally, perimortem cesarean should be initiated within four minutes and delivery of the newborn should be completed within five minutes (known as the “four-minute rule” or “the five-minute rule”). Perimortem instrumental vaginal delivery is appropriate if it can be achieved within this timeframe. To achieve this timeframe, delivery needs to be performed at the location of the arrest, which is often not an operating room [3,29].

The rationale for this approach is based on case reports, small case series, and experimental data showing [15,30-36]:

- Irreversible brain damage can occur in nonpregnant individuals after four to six minutes of anoxia
- Pregnant women become anoxic sooner than nonpregnant women because of decreased functional residual capacity.
- If the uterine fundus is at or above the umbilicus, ineffective resuscitation efforts may become effective when the uterus is no longer gravid and potentially causing aortocaval compression. Sudden substantial improvement in hemodynamics with a return of pulse and blood pressure immediately after perimortem cesarean delivery has been observed [3,37-40].
- Intact fetal survival diminishes as the time between maternal death and delivery lengthens

Despite implementation of maneuvers to ameliorate aortocaval compression, CPR may not restore spontaneous circulation or provide adequate cardiac output. Blood flow during CPR is produced by mechanical compression of the heart between the sternum and the spine and phasic fluctuations in intrathoracic pressure. Despite appropriate use of leftward uterine displacement, the mechanical effects of the gravid uterus can decrease venous return from the inferior vena cava, obstruct blood flow through the abdominal aorta, and diminish thoracic compliance, all of which contribute to unsuccessful CPR [41]. Without restoration of cardiac output, both mother and fetus are at risk for hypoxia and eventually anoxia, especially when interruption of normal cardiac and respiratory function persists beyond four minutes [42]. Although it may be counterintuitive to operate on a hemodynamically unstable patient, cesarean delivery may be life-saving for both mother and fetus in this situation. Delivery of the baby empties the uterus, relieving the aortocaval compression. This results in a 60 to 80 percent increase in cardiac output, thereby increasing the likelihood of maternal survival [43].

Evidence for the five-minute rule — Although there have been no controlled clinical trials in this area, a review of case reports of perimortem cesarean delivery from 1900 to 1985 suggested that normal neonatal neurological outcome was most likely when delivery was completed within five minutes of maternal cardiac arrest. In this series, 42 of 42 infants delivered within five minutes had a normal neurological outcome compared with seven of eight infants delivered within 6 to 10 minutes, six of seven infants delivered within 11 to 15 minutes, 0 of 1 infant delivered between 16 and 20 minutes, and one of three infants delivered within 21 to 25 minutes [34].

The authors' subsequent evaluation of perimortem cesarean cases reported from 1985 to 2004 noted perimortem cesarean was associated with spontaneous return of maternal circulation or improvement in maternal hemodynamic status in 12 of 20 cases, particularly when the delivery was completed within five minutes of maternal arrest [33]. No case of perimortem cesarean delivery resulted in deterioration of the maternal condition, although these case reports are highly subject to reporting bias. Similarly, neonatal outcomes were best when delivery was completed within five minutes; 9 of 12 infants delivered within this timeframe had a normal neurological outcome (neonatal outcome was not reported for three infants); two of six infants born from 6 to 15 minutes after maternal cardiac arrest had normal outcomes (one infant outcome was not reported), and four of seven infants delivered after 15 minutes of maternal arrest had normal outcomes. Additional features favoring infant survival include absence of sustained pre-arrest maternal hypoxia, minimal or no signs of fetal distress before maternal cardiac arrest, aggressive and effective resuscitative efforts for the mother, and neonatal intensive care unit on site of the emergency cesarean delivery.

Practically, the goal of delivering the infant within five minutes has been difficult to achieve [4,44]. In a literature review including 57 perimortem cesarean deliveries with time to delivery information, the time was <5 minutes in four cases, <10 minutes in 18 cases, and <15 minutes in 32 cases [44]. Only peripartum cesarean delivery within 10 minutes and in-hospital arrest were predictive of maternal survival. Only in-hospital arrest was predictive of neonatal survival. (See 'Outcome' below.)

Minimum gestational age — The minimum gestational age for perimortem cesarean delivery is controversial. Although physiologically aortocaval compression begins as early as 20 weeks, there is some imprecision within the range of 20 to 24 weeks [15]. Neonatal viability is also an imprecise assessment, as it is uncertain which extremely preterm infants, particularly those born at 23 and 24 weeks of gestation, have a reasonable chance of survival without severe deficits. Most centers would provide full neonatal support to infants at least 24 weeks of gestation and some centers provide this level of care to infants greater than 22 weeks of gestation [45]. (See "Periviable birth (Limit of viability)".)

Given these variables, perimortem hysterotomy is a reasonable option for pregnancies ≥20 weeks of gestation/uterine size at or above the umbilicus to relieve aortocaval compression and facilitate return of spontaneous circulation, regardless of fetal status (alive or demised) [13,33]. If the fetus is alive, there may be a neonatal benefit from perimortem hysterotomy at >22 to 24 weeks of gestation.

Delivery issues — As discussed above, perimortem cesarean should be initiated within four minutes after cardiac arrest; thus, transporting the patient to an operating room is not a priority [29]. An emergency cesarean delivery kit (eg, preloaded scalpel, sutures, needle holders, towel clips, retractors, forceps, scissors, suction tube, sponges, Kelly clamps, uterine pack, equipment for neonatal care/resuscitation) should be part of the resuscitation cart in patient care areas that commonly serve pregnant women or transported to the location of the pregnant patient who has arrested. In the United States, there are no published reports of physician liability for performing perimortem cesarean delivery without consent following maternal cardiac arrest [7].

Chest compressions should be continued without interruption until return of spontaneous circulation and broad spectrum antibiotics are administered to decrease the risk of postpartum infection. (See "Cesarean delivery: Preoperative planning and patient preparation", section on 'Antibiotic prophylaxis'.)

We suggest a vertical skin incision to provide fast entry, adequate uterine exposure, and access to the diaphragm, which may be useful for further resuscitative interventions (see 'Additional interventions' below). Bleeding may be minimal during the procedure due to hypoperfusion. Extraction of the placenta and closure of the hysterotomy are important steps to prevent subsequent hemorrhage when hemodynamic stability is eventually restored. (See "Cesarean delivery: Surgical technique".)

Assisted vaginal delivery is appropriate if the cervix is fully dilated and the neonate is at a low station and can be delivered within five minutes of maternal cardiorespiratory collapse.

Oxytocin is given routinely after delivery to reduce maternal blood loss and the risk of postpartum hemorrhage. We suggest a continuous intravenous infusion of a dilute oxytocin solution (eg, 20 milliunits/minute). Intramyometrial administration of 10 units oxytocin is an effective alternative to intravenous infusion. Intravenous **bolus injection of oxytocin should be avoided** because of the risk for significant hypotension, cardiovascular collapse, and death. (See "Management of the third stage of labor: Drug therapy to minimize hemorrhage", section on 'Oxytocin'.)

Use of medications for CPR during pregnancy — Given the lethality of cardiopulmonary arrest, the benefits from use of potentially life-saving drugs outweigh any known or possible fetal risks. All medications at the same doses (including amiodarone) for treatment of cardiopulmonary arrest in the nonpregnant patient are used for the pregnant patient.

Epinephrine is preferable to vasopressin in pregnant women, given that vasopressin is not clearly superior to epinephrine and causes uterine contractions [10].

Magnesium sulfate is commonly used in obstetrics for a variety of indications (prevention of eclamptic seizures, fetal neuroprotection before preterm delivery, tocolysis). If magnesium toxicity is suspected, magnesium sulfate infusion should be discontinued and calcium chloride (10 mL of a 10 percent solution) or calcium gluconate (30 mL of a 10 percent solution) should be given intravenously or intraosseously early in the resuscitation process. (See "Preeclampsia: Management and prognosis".)

Advanced cardiac life support (ACLS) guidelines do **not** recommend routine use of sodium bicarbonate during CPR, but it may be useful in life-threatening hyperkalemia or tricyclic antidepressant overdose (see "Therapies of uncertain benefit in basic and advanced cardiac life support"). However, if neither of these conditions is known or strongly suspected to be present, bicarbonate is not indicated and may worsen fetal acidosis. Since bicarbonate crosses the placenta very slowly, overcorrection of maternal acidosis will lead to pooling of carbon dioxide in the fetal compartment [14].

Arrhythmias are difficult to control, especially those resulting from bupivacaine toxicity. Amiodarone, a primary drug in the ACLS arrhythmia treatment algorithm, is the favored treatment for severe bupivacaine-induced arrhythmias; administration of the local anesthetic lidocaine to treat local anesthetic toxicity is not indicated as it has had equivocal success [46]. The arrhythmias are often refractory to therapy; emergency cardiopulmonary bypass may be life-saving until the drug dissociates from cardiac tissue [47].

Early administration of lipid emulsion (eg, 20 percent intralipid) is becoming a significant component in resuscitation of local anesthetic-induced cardiotoxicity. This therapy, which theoretically acts as a lipid sink that binds lipid-soluble local anesthetics (eg, bupivacaine), has rapidly gained acceptance [48] since the first case reports documenting its efficacy were published in 2006 [49,50]. Lipid rescue should be initiated at the first signs of severe systemic local anesthetic toxicity, while the airway is being secured. An intravenous bolus of 1.5 mL/kg lean body mass of 20 percent lipid emulsion is given over one minute, followed by an infusion of 0.25 mL/kg/min until at least 10 minutes following successful achievement of circulatory stability. If circulatory stability is not obtained within five minutes, a second 1.5 mL/kg bolus may be administered, followed by an infusion of 0.5 mL/kg/min. The maximum total cumulative dose of lipid is 10 mL/kg over 30 minutes [51]. Consultation with a medical toxicologist or regional poison center is advisable when lipid emulsion therapy is being considered for treatment of local anesthetic toxicity.

Although the anesthetic propofol is formulated as a 10 percent lipid emulsion, it should not be used for lipid rescue, since the dose needed to treat local anesthetic toxicity would result in massive hypotension that may counteract any positive effect.

The American Society of Regional Anesthesia and Pain Medicine has published a checklist for treatment of local anesthetic systemic toxicity [52]. During a simulated local anesthetic critical event, use of this checklist led to more critical management steps completed [52]. A consensus statement by the Society for Obstetric Anesthesia and Perinatology on the management of cardiac arrest during pregnancy encouraged the use of checklists to improve team performance [21]. Maternal resuscitation guidelines from the American Heart Association also encourage institutions to create and utilize checklists during obstetric crises and to institute mock code drills of maternal cardiac arrest.

ADDITIONAL INTERVENTIONS

Diagnostic interventions

Transesophageal echocardiography — Widespread availability of cardiothoracic surgery and perfusionist teams offers an alternative strategy for continued resuscitation during cardiopulmonary arrest in the operating room [13]. Transesophageal echocardiography (TEE) is a quick, portable, and reliable means of identifying potential causes of hemodynamic collapse during labor and delivery, as it provides detailed information about left ventricular systolic function and can detect previously unrecognized cardiac conditions [53-58]. TEE is helpful for placement of venous and arterial cannulae for extracorporeal membranous oxygenation and placement of intraaortic balloon counterpulsation, as well as for assessing the effects of intraaortic balloon counterpulsation and inotropic agents [59].

Management interventions in selected clinical scenarios

Cardiovascular collapse

- **Direct cardiac massage** — After 15 minutes of unsuccessful closed chest cardiopulmonary resuscitation (CPR), direct cardiac massage via thoracotomy or through the diaphragm (if the abdomen is open) can be implemented [60]. Direct cardiac massage results in near normal systemic perfusion throughout the compression cycle and with higher cranial and myocardial flow than achieved with external chest compressions of conventional CPR [61].

- **Intraaortic balloon pump, cardiopulmonary bypass, and extracorporeal membrane oxygenation** Intraaortic balloon pump, cardiopulmonary bypass, and extracorporeal membrane oxygenation have been used to treat patients with cardiovascular collapse, including those with pulmonary embolism, local anesthetic toxicity, illicit drug use such as cocaine, amniotic fluid embolism and pulseless electrical activity. Case reports have described successful resuscitation using cardiopulmonary bypass intraoperatively during cesarean delivery and postpartum in women with amniotic fluid embolism and pulmonary embolism [53,62]. However, use of this technology is hampered by the preparation time required to institute the intervention. (See "Extracorporeal membrane oxygenation (ECMO) in adults" and "Amniotic fluid embolism syndrome".)

ST elevation myocardial infarction — For pregnant women with ST elevation myocardial infarction, percutaneous coronary intervention is the preferred reperfusion strategy since fibrinolytics are relatively contraindicated in pregnancy [63]. ST elevation myocardial infarction in pregnant women may be secondary to coronary artery dissection; coronary artery catheterization is required for diagnosis and management. (See "Acute myocardial infarction and pregnancy" and "Spontaneous coronary artery dissection".)

Massive pulmonary embolism and ischemic stroke — Successful systemic thrombolysis has been reported for massive pulmonary embolism and for ischemic stroke during pregnancy [64]. If systemic thrombolysis is utilized, excessive bleeding may complicate imminent cesarean delivery or the postoperative course of patients who were recently delivered. Transfusion of blood products should be anticipated: In one review of postpartum systemic thrombolytic therapy, blood transfusion was necessary in 12 of 13 cases, a large amount of blood was required for transfusion in 7 of these 12 cases, and laparotomy was eventually required to control bleeding in 5 of the 12 cases (including 3 hysterectomies) [65]. Severe bleeding was higher in patients that had a cesarean delivery, and laparotomy was only necessary in patients that had a cesarean delivery. Management of pulmonary embolism and ischemic stroke, including thrombolysis, is discussed separately. (See "Treatment, prognosis, and follow-up of acute pulmonary embolism in adults" and "Thrombolytic (fibrinolytic) therapy in acute pulmonary embolism and lower extremity deep vein thrombosis" and "Initial assessment and management of acute stroke" and "Approach to reperfusion therapy for acute ischemic stroke".)

POSTARREST CARE — In the absence of need for chest compression, the patient should be placed at 90 degrees left lateral tilt to avoid aortocaval compression, which can also occur postpartum since the uterus remains enlarged [10].

Core temperature lability is associated with increased mortality after in-hospital cardiac arrest. Hyperthermia should be avoided [66]. It is unclear whether therapeutic hypothermia is beneficial. The American Heart Association recommends avoiding routine use of therapeutic hypothermia because in undelivered patients it may not be safe for the fetus (pregnant women have been excluded from trials on therapeutic hypothermia) and in postpartum patients it may impair coagulation and contribute to bleeding complications [10]. However, the induction of mild to moderate hypothermia (target temperature 32 to 34 degrees Celsius for 24 hours) may be beneficial in comatose pregnant women and has been used successfully in this setting [67,68]. It should also be considered in women not following commands or showing purposeful movements following resuscitation from cardiac arrest. Temperature issues are discussed in more detail separately. (See "Post-cardiac arrest management in adults", section on 'Targeted temperature management (TTM) and therapeutic hypothermia (TH)'.)

In the hypothermic woman, the fetal heart rate may have a low baseline (90 to 100 beats per minute) with diminished variability [69]. Absent variability and fetal heart decelerations suggest deterioration in the fetal status; delivery should be considered if the fetus is at a viable gestational age.

OUTCOME — Cardiac arrest in pregnant women is associated with high maternal and neonatal fatality rates [3-6,44]. Maternal mortality rates of 30 to 80 percent and neonatal mortality rates of 60 percent have been reported in large studies. As an example, in a literature review including 94 cases of maternal cardiac arrest, 46 percent of mothers died before hospital discharge [44]. The reviewers believed perimortem cesarean delivery was beneficial for one-third of mothers and was not harmful in any case. Overall neonatal survival was 64 percent (42/66) in singleton pregnancies with a potentially viable fetus delivered by perimortem cesarean delivery; neonatal survival was attributed to perimortem cesarean delivery in half of these cases. The mean time from arrest to delivery for newborn survivors was 14±11 minutes, versus 22±13 minutes for newborn non-survivors. Approximately 12 percent of maternal survivors and 21 percent of neonatal survivors had poor neurological outcomes (Cerebral Performance Category 3/4).

Maternal and neonatal survival depends on several factors, including the underlying etiology for the arrest, maternal location at the time of the arrest (out of hospital versus in hospital), speed of resuscitative efforts, and the skills and resources of the healthcare providers [70]. A high survival rate in series with a high proportion of anesthetic complications may be due to the opportunity for immediate resuscitation in the operating room or labor and delivery room by skilled personnel with appropriate resources [6], and possibility better pre-arrest maternal condition.

Although there is a high risk of maternal mortality after cardiac arrest, in-hospital survival appears to be higher than that for nonpregnant reproductive age women [71,72]. This may be due to differences between the two groups in clinical risk factors and/or differences in intensity of patient monitoring among various hospital units.

SUMMARY AND RECOMMENDATIONS

- The A through H mnemonic is useful as a reminder of the causes of cardiac arrest in pregnant women (see 'Etiology' above):
  - A: Anesthetic complications, Accident/trauma
  - B: Bleeding
  - C: Cardiac
  - D: Drugs
  - E: Embolic causes
  - F: Fever
  - G: General including hypoxia, electrolyte disturbances
  - H: Hypertension
- Key principles for resuscitation of pregnant women are (see 'Key principles for resuscitation' above):
  - Call a maternal code blue, which should include a multi-disciplinary team.
  - If the uterus is above the umbilicus, displace it off aortocaval vessels. We suggest manually displacing the uterus laterally to the patient's left rather than tilting the entire patient (**Grade 2C**). A hand is used to apply maximal leftward push to the right upper border of the uterus to achieve displacement of about 1.5 inches from the midline. Leave the upper torso supine. (See 'Avoiding aortocaval compression' above.)
  - Assume a difficult airway. Bag-mask ventilation with 100 percent oxygen and suctioning of the airway are critical before intubation in a pregnant woman. Oxygenate well to avoid desaturation and avoid respiratory alkalosis; ventilation volumes may need to be lower than in nonpregnant women if the uterus is very large. (See 'Airway management' above.)
  - Place hands for chest compression at the same location and perform compressions in the same way as in nonpregnant adults. (See 'Chest compressions' above.)
  - Do not delay usual measures such as defibrillation and the administration of medications. Energy requirements for adult defibrillation are the same as in nonpregnant women. All medications at the same doses for treatment of cardiopulmonary arrest in the nonpregnant patient are used for the pregnant patient. (See 'Defibrillation' above and 'Use of medications for CPR during pregnancy' above.)
  - Designate a dedicated timer to notify the resuscitation team when four minutes have elapsed after the onset of a maternal cardiac arrest. (See 'Delivery as part of the resuscitation process' above.)

- If there is no return of spontaneous circulation with the usual resuscitation measures and the uterine fundus is at or beyond the umbilicus, we agree with AHA guidelines that recommend beginning perimortem cesarean (resuscitative hysterotomy) at four minutes and completing delivery of the newborn by five minutes following cardiac arrest (**Grade 1C**). In pregnant women, delivery early in the resuscitation process is a key intervention for improving success rates. Assisted vaginal delivery is appropriate if the neonate can be delivered within five minutes of maternal cardiorespiratory collapse. (See 'Delivery as part of the resuscitation process' above.)

- Perform delivery at the site of resuscitation. (See 'Delivery issues' above.)

- Post-arrest, induction of mild to moderate hypothermia (target temperature 32 to 34 degrees Celsius for 24 hours) is reasonable in women who are comatose or not following commands or showing purposeful movements following resuscitation. It is not used routinely because in undelivered patients it may not be safe for the fetus, and in postpartum patients it may impair coagulation and contribute to bleeding complications. (See 'Postarrest care' above.)

- Cardiac arrest in pregnant women is associated with high maternal and neonatal fatality rates. Survival of the mother and neonate depend on several factors, including the underlying etiology for the arrest, maternal location at the time of the arrest (out-of-hospital versus in-hospital), speed of resuscitative efforts, and the skills and resources of the healthcare providers. (See 'Outcome' above.)

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Topic 14184 Version 30.0

GRAPHICS

Some causes of cardiac arrest in pregnancy

Pulmonary causes
Embolism
Thromboembolism
Amniotic fluid embolism
Asthma
Cardiac causes
Myocardial infarction
Congenital valvular disease
Arrhythmias
Cardiomyopathy of pregnancy
Hemorrhagic causes
Uterine atony
Abnormally adherent placentation
Abruptio placentae
Placenta previa
Disseminated intravascular coagulation
Infection/sepsis
Anesthesia-related causes
Failed intubation
Aspiration
Intravascular injection of local anesthetics
High neuraxial block
Hypertensive complications
Stroke
Preeclampsia/eclampsia
Pheochromocytoma
Medication-related complications
Tocolytic toxicities
Illicit drug use
Hypermagnesemia
Anaphylaxis
Trauma
Intimate partner violence
Motor vehicle accident

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Graphic 70707 Version 6.0

Maternal cause-specific mortality in cardiac arrest

	Potential proximate etiology of maternal cardiac arrest, n (%)	Cause-specific cardiac arrest frequency per 1000 women with each condition	Survival to hospital discharge,* n (%)
Postpartum hemorrhage	1349 (27.9)	0.8	739 (55.1)
Antepartum hemorrhage	813 (16.8)	0.9	433 (53.2)
Heart failure	645 (13.3)	15.6	458 (71.1)
Amniotic fluid embolism	645 (13.3)	252.7	337 (52.5)
Sepsis	544 (11.2)	2.1	256 (46.9)
Anesthesia complication	379 (7.8)	29.5	310 (81.9)
Aspiration pneumonitis	346 (7.1)	20.3	287 (82.9)
Venous thromboembolism	346 (7.1)	43.9	144 (41.5)
Eclampsia	296 (6.1)	6.2	226 (76.5)
Puerperal cerebrovascular disorder	212 (4.4)	13.6	85 (40)
Trauma	125 (2.6)	3.9	29 (23.3)
Pulmonary edema	118 (2.4)	11.2	83 (70.9)
Acute myocardial infarction	150 (3.1)	89.8	85 (56.3)
Magnesium toxicity	66 (1.4)	5.2	57 (85.9)
Status asthmaticus[¶]	54 (1.1)	12.6	29 (53.7)
Anaphylaxis[¶]	15 (0.3)	10.8	15 (100)
Aortic dissection/rupture[¶]	14 (0.3)	31	0

Distribution of Maternal Cardiac Arrests (n = 4843), the Nationwide Inpatient Sample (NIS) 1998-2011. Numbers of arrests from local anesthetic toxicity cannot be reported due to restrictions on reporting small cell sizes.

%: percent.
* Survival is missing for 0.2% of those with cardiopulmonary arrest.
¶ Estimates with a relative standard error (ie, standard error/weighted estimate) >0.30 may not be reliable.

Graphic 94579 Version 4.0

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