

## Cardiac Arrest in Pregnancy A Scientific Statement From the American Heart Association

Farida M. Jeejeebhoy, MD, Chair; Carolyn M. Zelop, MD; Steve Lipman, MD; Brendan Carvalho, MD; Jose Joglar, MD; Jill M. Mhyre, MD; Vern L. Katz, MD; Stephen E. Lapinsky, MB BCh, MSc; Sharon Einav, MD; Carole A. Warnes, MD; Richard L. Page, MD; Russell E. Griffin, LP, FP-C; Amish Jain, MD; Katie N. Dainty, PhD; Julie Arafeh, RN, MS; Rory Windrim, MD; Gideon Koren, MD; Clifton W. Callaway, MD, PhD; on behalf of the American Heart Association Emergency Cardiovascular Care Committee, Council on Cardiopulmonary, Critical Care, Perioperative and Resuscitation, Council on Cardiovascular Diseases in the Young, and Council on Clinical Cardiology

**Abstract**—This is the first scientific statement from the American Heart Association on maternal resuscitation. This document will provide readers with up-to-date and comprehensive information, guidelines, and recommendations for all aspects of maternal resuscitation. Maternal resuscitation is an acute event that involves many subspecialties and allied health providers; this document will be relevant to all healthcare providers who are involved in resuscitation and specifically maternal resuscitation. (*Circulation*. 2015;132:1747-1773. DOI: 10.1161/CIR.0000000000000300.)

**Key Words:** AHA Scientific Statements ■ cardiopulmonary resuscitation ■ heart arrest ■ pregnancy

Cardiac arrest in pregnancy is one of the most challenging clinical scenarios. Although most features of resuscitating a pregnant woman are similar to standard adult resuscitation, several aspects and considerations are uniquely different. The most obvious difference is that there are 2 patients, the mother and the fetus. Caregivers must have a thorough understanding of maternal mortality to best prevent and treat cardiac arrest in pregnancy. Maternal mortality is defined as the death of a woman during pregnancy and up to 42 days after delivery or termination of pregnancy, provided that the cause of death is related to or aggravated by the pregnancy or its management. Recent data from the US Nationwide Inpatient Sample suggest that cardiac arrest occurs in 1:12 000 admissions for delivery.<sup>1</sup> Globally, 800 maternal deaths occur daily.<sup>2,3</sup> Maternal mortality trends in the United States as reported by the Centers for Disease Control and Prevention from 1989 to 2009 have documented a steady increase from 7.2 deaths

per 100 000 live births in 1987 to 17.8 deaths per 100 000 live births in 2009.<sup>4</sup> However, maternal mortality rates are just a small representation of maternal critical events; maternal near-miss data should be considered. A maternal near miss is defined as “a woman who nearly died but survived a complication that occurred during pregnancy, childbirth, or within 42 days of termination of pregnancy.”<sup>5</sup> Data from the Netherlands show an incidence of maternal near miss of 1:141 in delivery wards.<sup>6</sup> Among cases with severe maternal morbidity, there was an overall case fatality rate of 1:53.<sup>6</sup> Knowledge deficits<sup>7,8</sup> and poor resuscitation skills<sup>9</sup> could be major contributors to poor outcomes once cardiac arrest has occurred. Despite these problems, recent data show that the rate of survival to hospital discharge after maternal cardiac arrest may be as high as 58.9%,<sup>1</sup> far higher than most arrest populations, further justifying appropriate training and preparation for such events despite their rarity.

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This scientific statement addresses all of the important factors related to maternal arrest, including maternal physiology as it relates to resuscitation, pre-event planning of the critically ill pregnant patient, risk stratification during pregnancy, management of the unstable pregnant patient, basic life support (BLS) in pregnancy, advanced cardiovascular life support (ACLS) in pregnancy, neonatal considerations, emergency medical service (EMS) care, cause of maternal arrest (with a comprehensive discussion found in the online-only Appendix), point-of-care instruments, immediate postarrest care, medicolegal considerations, and knowledge translation, training, and education recommendations.

## Methods

Authors with expertise in maternal resuscitation and relevant areas of specialty were selected to contribute to this statement. Selection of the writing group was performed in accordance with the American Heart Association's (AHA's) conflict-of-interest management policy. Relevant literature considered for inclusion in this statement was identified through an up-to-date search strategy of the process used for the 2010 International Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science With Treatment Recommendations and the 2010 International Liaison Committee on Resuscitation worksheets, PubMed, Embase, and an AHA master resuscitation reference library. The search also included a review of bibliographies and manual searches of key articles. Participants volunteered to write sections relevant to their expertise and experience. Drafts of each section were written and sent to the chair of the writing group for incorporation into a single document, which was then edited. The edited document was discussed during Webinars in which participants provided feedback to the primary author of each section and discussed the document as a group. On the basis of these discussions and consensus, the sections were then edited accordingly by the primary author, returned to the chair, and reincorporated into the single document. Further edits were performed by the chair, and a final version of the document was produced. The final document was circulated among all contributors, and consensus was achieved. Recommendations were generated from this process and then assigned a class of recommendation and level of evidence (Table 1). The final document was submitted for independent peer review and has been approved for publication by the AHA Emergency Cardiovascular Care Committee and Science Advisory and Coordinating Committee.

## Important Physiological Changes in Pregnancy

Fetal development and maternal maintenance of pregnancy require multiorgan physiological adaptations that are pertinent to the team responding to cardiopulmonary arrest during pregnancy.

Cardiac output rises 30% to 50% as a result of increased stroke volume and, to a lesser extent, increased maternal heart rate (15–20 bpm).<sup>10,11</sup> Systemic vascular resistance decreases as a result of an increase in several endogenous vasodilators, including progesterone, estrogen, and nitric oxide, leading to a decrease in mean arterial pressure, reaching a nadir in the second trimester.<sup>12</sup> The enlarging uterus can produce increased afterload through compression of the aorta and decreased cardiac return through compression of the inferior vena cava, starting at  $\approx$ 12

to 14 weeks of gestational age.<sup>13</sup> As a result, the supine position, which is most favorable for resuscitation, can lead to hypotension.<sup>13,14</sup> A magnetic resonance imaging study comparing the maternal hemodynamics in the left lateral position with those in the supine position was performed.<sup>15</sup> This study found that at 20 weeks of gestational age, there was a significant increase in ejection fraction of 8% and stroke volume of 27% in the left lateral position. At 32 weeks, there was a significant increase in ejection fraction of 11%, in end-diastolic volume of 21%, in stroke volume of 35%, and in cardiac output of 24% in the left lateral position.<sup>15</sup> Uteroplacental blood flow increases from 50 to close to 1000 mL/min during pregnancy, receiving up to a maximum of 20% of maternal cardiac output at term.<sup>16</sup> Expanded intravascular volume and a decrease in uterine vascular resistance facilitate sufficient uterine placental blood. Overall, uterine vascular reactivity is altered, characterized by reduced tone, enhanced vasodilation, and blunted vasoconstriction. Systemic hypotension can overwhelm the compensatory mechanisms, which attempt to maintain uterine blood flow.

Functional residual capacity decreases by 10% to 25% during pregnancy as the uterus enlarges and elevates the diaphragm. Increased ventilation (ie, an increase in tidal volume and minute ventilation) occurs, beginning in the first trimester, reaching a level 20% to 40% above baseline by term, mediated by the elevated serum progesterone levels.<sup>17</sup> This produces a mild respiratory alkalosis with compensatory renal excretion of bicarbonate, resulting in an arterial carbon dioxide pressure of  $\approx$ 28 to 32 mm Hg (3.7–4.3 kPa) and a plasma bicarbonate level of 18 to 21 mEq/L.<sup>18</sup> Oxygen consumption increases because of the demands of the fetus and maternal metabolic processes, reaching a level 20% to 33% above baseline by the third trimester.<sup>19</sup> The reduced functional residual capacity reservoir and increased consumption of oxygen are responsible for the rapid development of hypoxemia in response to hypoventilation or apnea in the pregnant woman.<sup>20</sup> The oxyhemoglobin dissociation curve is shifted to the right in the mother during pregnancy ( $P_{50}$  increases from 27 to 30 mm Hg). A higher partial pressure of oxygen is therefore required to achieve the same maternal oxygen saturation. The same curve is shifted to the left in the fetus ( $P_{50}$  is 19 mm Hg), conferring relative resilience to hypoxic conditions. Upper airway edema and friability occur as a result of hormonal effects and may reduce visualization during laryngoscopy and increase the risk of bleeding.

Pregnancy is characterized by glomerular hyperfiltration and increased renal blood flow by 40% to accommodate the maternal role of fetal detoxification of metabolic byproducts and maintenance of maternal osmoregulation in the face of increased circulatory intravascular volume. Altered tubular function prevents wasting of glucose, amino acids, and proteins required by both maternal and fetal metabolisms. On balance, Starling forces favor a narrowing of the oncotic pressure–wedge pressure gradient, increasing the tendency for pulmonary edema to develop.<sup>21</sup>

Progesterone relaxes gastroesophageal sphincters and prolongs transit times throughout the intestinal tract during the second and third trimesters,<sup>22,23</sup> predisposing the patient to aspiration of stomach contents.

Drug metabolism is altered by several different mechanisms in pregnancy.<sup>23a–23d</sup> In addition to changes in renal

Table 1. Applying Classification of Recommendations and Level of Evidence

ESTIMATE OF CERTAINTY (PRECISION) OF TREATMENT EFFECT	SIZE OF TREATMENT EFFECT					
	CLASS I <i>Benefit &gt;&gt;&gt; Risk</i> Procedure/Treatment <b>SHOULD</b> be performed/ administered	CLASS IIa <i>Benefit &gt;&gt; Risk</i> Additional studies with focused objectives needed <b>IT IS REASONABLE</b> to per- form procedure/administer treatment	CLASS IIb <i>Benefit ≥ Risk</i> Additional studies with broad objectives needed; additional registry data would be helpful Procedure/Treatment <b>MAY BE CONSIDERED</b>	CLASS III <i>No Benefit</i> or CLASS III <i>Harm</i>		
				Procedure/ Test	Treatment	
				COR III: No benefit	Not Helpful	No Proven Benefit
				COR III: Harm	Excess Cost w/o Benefit or Harmful	Harmful to Patients
<b>LEVEL A</b> Multiple populations evaluated* Data derived from multiple randomized clinical trials or meta-analyses	<ul style="list-style-type: none"> <li>Recommendation that procedure or treatment is useful/effective</li> <li>Sufficient evidence from multiple randomized trials or meta-analyses</li> </ul>	<ul style="list-style-type: none"> <li>Recommendation in favor of treatment or procedure being useful/effective</li> <li>Some conflicting evidence from multiple randomized trials or meta-analyses</li> </ul>	<ul style="list-style-type: none"> <li>Recommendation's usefulness/efficacy less well established</li> <li>Greater conflicting evidence from multiple randomized trials or meta-analyses</li> </ul>	<ul style="list-style-type: none"> <li>Recommendation that procedure or treatment is not useful/effective and may be harmful</li> <li>Sufficient evidence from multiple randomized trials or meta-analyses</li> </ul>		
<b>LEVEL B</b> Limited populations evaluated* Data derived from a single randomized trial or nonrandomized studies	<ul style="list-style-type: none"> <li>Recommendation that procedure or treatment is useful/effective</li> <li>Evidence from single randomized trial or nonrandomized studies</li> </ul>	<ul style="list-style-type: none"> <li>Recommendation in favor of treatment or procedure being useful/effective</li> <li>Some conflicting evidence from single randomized trial or nonrandomized studies</li> </ul>	<ul style="list-style-type: none"> <li>Recommendation's usefulness/efficacy less well established</li> <li>Greater conflicting evidence from single randomized trial or nonrandomized studies</li> </ul>	<ul style="list-style-type: none"> <li>Recommendation that procedure or treatment is not useful/effective and may be harmful</li> <li>Evidence from single randomized trial or nonrandomized studies</li> </ul>		
<b>LEVEL C</b> Very limited populations evaluated* Only consensus opinion of experts, case studies, or standard of care	<ul style="list-style-type: none"> <li>Recommendation that procedure or treatment is useful/effective</li> <li>Only expert opinion, case studies, or standard of care</li> </ul>	<ul style="list-style-type: none"> <li>Recommendation in favor of treatment or procedure being useful/effective</li> <li>Only diverging expert opinion, case studies, or standard of care</li> </ul>	<ul style="list-style-type: none"> <li>Recommendation's usefulness/efficacy less well established</li> <li>Only diverging expert opinion, case studies, or standard of care</li> </ul>	<ul style="list-style-type: none"> <li>Recommendation that procedure or treatment is not useful/effective and may be harmful</li> <li>Only expert opinion, case studies, or standard of care</li> </ul>		
Suggested phrases for writing recommendations	should is recommended is indicated is useful/effective/beneficial	is reasonable can be useful/effective/beneficial is probably recommended or indicated	may/might be considered may/might be reasonable usefulness/effectiveness is unknown/unclear/uncertain or not well established	COR III: No Benefit is not recommended is not indicated should not be performed/ administered/ other is not useful/ beneficial/ effective	COR III: Harm potentially harmful causes harm associated with excess morbidity/mortality should not be performed/ administered/ other	
Comparative effectiveness phrases†	treatment/strategy A is recommended/indicated in preference to treatment B treatment A should be chosen over treatment B	treatment/strategy A is probably recommended/indicated in preference to treatment B it is reasonable to choose treatment A over treatment B				

A recommendation with Level of Evidence B or C does not imply that the recommendation is weak. Many important clinical questions addressed in the guidelines do not lend themselves to clinical trials. Although randomized trials are unavailable, there may be a very clear clinical consensus that a particular test or therapy is useful or effective.

\*Data available from clinical trials or registries about the usefulness/efficacy in different subpopulations, such as sex, age, history of diabetes, history of prior myocardial infarction, history of heart failure, and prior aspirin use.

†For comparative effectiveness recommendations (Class I and IIa; Level of Evidence A and B only), studies that support the use of comparator verbs should involve direct comparisons of the treatments or strategies being evaluated.

physiology, gastrointestinal absorption and gastrointestinal transit affect bioavailability. Protein binding changes also alter the free fraction of the drug available. Steroid-induced acceleration of the hepatic P450 metabolism and increased renal clearance will also lower circulating drug levels.

### Estimating Gestational Age

Management decisions made during a maternal cardiac arrest may require estimation of gestational age. Symphysis fundal height is the measurement from the top of the maternal pubic bone to the top of the uterine fundus. In a singleton pregnancy, with the fetus in a longitudinal lie, this height in centimeters will approximately correspond to the gestational age in weeks when

measured between 16 and 36 weeks of gestation. If a tape measure is not available, finger breadths are usually used as a surrogate for the centimeters. Classically accepted rule-of-thumb landmarks may also be used: Gestational age is 12 weeks if the uterus is palpable at above the pubic symphysis, 20 weeks if the uterus is palpable at the level of the umbilicus,<sup>24</sup> and 36 weeks if the uterus is palpable at the level of the xiphisternum. However, the fundus can be a poor predictor of gestational age and may reach the umbilicus between 15 and 19 weeks of gestation.<sup>25</sup> In the last month of pregnancy, after 36 weeks of gestation, there may be diminution of the fundal height from 36 down to ≈32 cm as the fetal head engages into the pelvis. Fundal height may also be skewed by other factors such as abdominal distention<sup>24</sup>



and increased body mass index; therefore, fundal height may be a poor predictor of gestational age.

## Recommendation

1. Code team members with responsibility for pregnant women should be familiar with the physiological changes of pregnancy that affect resuscitation technique and potential complications (*Class I; Level of Evidence C*).

## The Critically Ill Pregnant Patient

### Pre-Event Planning

The critically ill pregnant patient may be managed in units not accustomed to managing obstetric patients such as the intensive care unit (ICU), coronary care unit, or medical or surgical ward. Teams on these units need to prepare for unexpected emergencies in these patients<sup>26</sup> by covering the following 4 important steps:

1. Preparation for cardiac arrest: Educate staff about the management of cardiac arrest in pregnancy.
2. Preparation for perimortem cesarean delivery (PMCD): Identify contact details or appropriate code calls to mobilize the entire maternal cardiac arrest response team, and ensure the availability of equipment for cesarean delivery and resuscitation of the neonate. In cultures that require consent for a PMCD, even in the event of a cardiac arrest, pre-event consent should be obtained.
3. Preparation for management of obstetric complications: Stock drugs and equipment commonly available in obstetric units, including oxytocin and prostaglandin F<sub>2α</sub>. Pre-event planning for power of attorney related to healthcare decisions should be done for the critically ill patient.
4. Decisions involving the resuscitation status of the neonate: Decisions about fetal viability should be made in collaboration with the obstetrician, neonatologist, and family. The decision depends on the gestational age and, to a significant degree, the neonatal facilities available. This information should be clearly documented.

### Severity of Illness and Early Warning Scores

The British Center for Maternal and Child Enquiries report of 2011 (2006–2008 triennium) has stated that timely recognition of pregnant women at risk of potentially life-threatening conditions plays an important role in the appropriate institution of treatment.<sup>27</sup> Brief checklists are provided for the identification of a number of conditions, including sepsis, respiratory distress, and neurological complications. The report also highlights the potential value of a modified early obstetric warning score. In a more recent publication, using a large British ICU data set, Carle et al<sup>28</sup> described the evaluation of several preexisting obstetric early warning scores and the development and validation of a new obstetric score and demonstrated excellent discrimination between survivors and nonsurvivors for this new score (area under the receiver-operating characteristic curve, 0.995). These scores can be used to monitor patients by clinical use of an early warning score

chart (Figure 1) and can accurately identify patients at high risk of mortality, although not specifically mortality resulting from cardiac arrest. Therefore, they are of value in patient management and triage.

## Recommendations

1. Pregnant women who become ill should be risk stratified by the use of a validated obstetric early warning score (*Class I; Level of Evidence C*).
2. Hospital units with a pregnant woman in their care should ensure that proper pre-event planning has been instituted, including preparation for maternal cardiac arrest and neonatal resuscitation (*Class I; Level of Evidence C*).

## Management of the Unstable Pregnant Patient

Rapid response to instability in the pregnant patient is essential for the prevention of cardiac arrest. Maternal hemodynamics must be optimized; hypoxemia must be treated; and intravenous access must be established.

## Recommendations<sup>29</sup>

1. The patient should be placed in a full left lateral decubitus position to relieve aortocaval compression (*Class I; Level of Evidence C*).
2. Administration of 100% oxygen by face mask to treat or prevent hypoxemia is recommended (*Class I; Level of Evidence C*).
3. Intravenous access should be established above the diaphragm to ensure that the intravenously administered therapy is not obstructed by the gravid uterus (*Class I; Level of Evidence C*).
4. Precipitating factors should be investigated and treated (*Class I; Level of Evidence C*).

## Cardiac Arrest Management

### Basic Life Support

The cardiac arrest in pregnancy in-hospital BLS algorithm should be used as a guide to management (Figure 2).

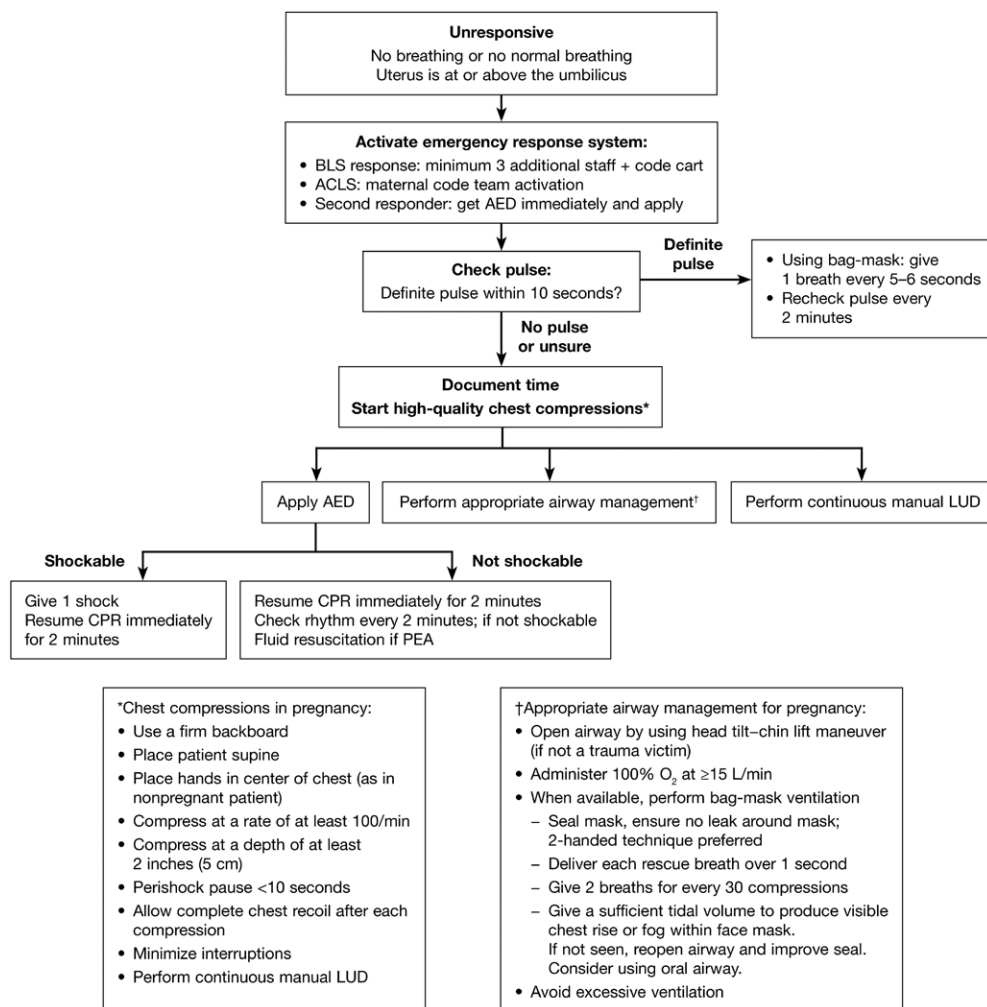
### First Responders

Nurses are often first responders in cardiopulmonary arrest; however, any hospital staff member may witness or discover a patient in arrest and should be able to begin basic emergency care.<sup>30</sup> Basic emergency care is crucial. Rapid mobilization of expert resuscitation teams and BLS performed competently until the arrival of these teams give the woman the best chance for return of spontaneous circulation (ROSC).

Accomplishing a coordinated, well-executed first response is challenging in patient care areas in which cardiopulmonary arrest rarely occurs, including obstetric units.<sup>30–41</sup> The unique physiology of pregnancy renders the patient vulnerable to hypoxemia and hemodynamic disadvantage, given the rapid development of desaturation with apnea and the presence of aortocaval compression when the patient is unconscious and supine. Therefore, all BLS interventions are essential and should be initiated rapidly and simultaneously once the rescuers arrive. First responders should

**Figure 1.** Example of a color-coded early warning score chart based on the score developed by Carle et al.<sup>28</sup> A score  $\geq 6$  should trigger a call for support from the intensive care unit or rapid response team and initiation of continuous monitoring of vital signs. BP indicates blood pressure; FiO<sub>2</sub>, fraction of inspired oxygen; GCS, Glasgow Coma Scale score; and Sat, saturation.

**Aortocaval Compression.** In the pregnant patient, supine positioning will result in aortocaval compression. Relief of aortocaval compression must be maintained continuously during resuscitative efforts and continued throughout postarrest care. Manual LUD should be used to relieve aortocaval compression during resuscitation. Historically, tilt has been used as an option to relieve aortocaval compression during resuscitation. Rees and Willis<sup>52</sup> found that at  $>30^\circ$  left lateral tilt, the manikin slid off the incline plane and that chest compression force was



**Figure 2.** Cardiac arrest in pregnancy in-hospital basic life support (BLS) algorithm: simultaneous C-A-B-U (chest compressions/current-airway-breathing-uterine displacement). ACLS indicates advanced cardiovascular life support; AED, automated external defibrillator; CPR, cardiopulmonary resuscitation; LUD, left uterine displacement; and PEA, pulseless electric activity.

reduced as the angle of inclination was increased. It has also been found that at >30° lateral tilt, inferior vena cava compression can still occur.<sup>53</sup> In addition, the heart has been shown to shift laterally during tilt<sup>54</sup> compared with the supine position. Therefore, chest compressions performed with the patient in a tilt could be significantly less effective than those performed with the patient in the usual supine position, and this could have a major impact on the chance of successful resuscitation.<sup>52,54</sup> In the nonarrest population, manual LUD compared with 15° left lateral tilt has been shown to result in less hypotension and a significantly lower ephedrine requirement during a cesarean delivery.<sup>55</sup> Additional benefits of manual LUD over tilt include easier access for both airway management and defibrillation. While manual LUD is performed, the patient can remain supine and receive usual resuscitative measures, including high-quality chest compressions without hindrance (Figure 3). Manual LUD can be performed from the left of the patient (Figure 4), where the uterus is cupped and lifted up and leftward off the maternal vessels, or from the right of the patient (Figure 3), where the uterus is pushed upward and leftward off the maternal vessels. The rescuer must be careful not to inadvertently push down,

which would increase the amount of inferior vena cava compression and negatively affect maternal hemodynamics.

## Recommendations<sup>29</sup>

1. Continuous manual LUD should be performed on all pregnant women who are in cardiac arrest in which the uterus is palpated at or above the umbilicus to relieve aortocaval compression during resuscitation (Class I; Level of Evidence C).
2. If the uterus is difficult to assess (eg, in the morbidly obese), attempts should be made to perform manual LUD if technically feasible (Class IIb; Level of Evidence C).

**Positioning of Hands During Chest Compressions.** There is no scientific evidence to support changing the recommendation for hand placement for chest compressions in the pregnant patient compared with the nonpregnant patient. Previous guidelines recommended placing the hands slightly higher on the sternum in the pregnant patient, but there are no scientific data to support this recommendation.



**Figure 3.** Manual left uterine displacement by the 1-handed technique from the right of the patient during adult resuscitation.

### Recommendation

1. The rescuer should place the heel of 1 hand on the center (middle) of the victim's chest (the lower half of the sternum) and the heel of the other hand on top of the first so that the hands overlap and are parallel (Class IIa; Level of Evidence C).

#### *Transporting Pregnant Women During Chest Compressions.*

Simulation of chest compressions on manikins has shown that the quality of CPR decreases during transport to the operating room.<sup>56</sup>

### Recommendation

1. Because an immediate cesarean delivery may be the best way to optimize the condition of the mother and fetus (see section on "PMCD"), this operation should optimally occur at the site of the arrest. A pregnant patient with in-hospital cardiac arrest should not be transported for cesarean delivery. Management should occur at the site of the arrest (Class I; Level of Evidence C). Transport to a facility that can perform a cesarean delivery may be required when indicated (eg, for out-of-hospital cardiac arrest or cardiac



**Figure 4.** Manual left uterine displacement by the 2-handed technique from the left of the patient.

arrest that occurs in a hospital not capable of cesarean delivery).

### *Defibrillation Issues During Pregnancy*

Prompt application of defibrillation in the setting of ventricular fibrillation or pulseless ventricular tachycardia is critical to maximize the likelihood of survival. This is no different in the pregnant patient. Transthoracic impedance remains unchanged during pregnancy compared with the nonpregnant state; therefore, the energy required for defibrillation during cardiac arrest in pregnancy would be the same as the most current recommendations for the nonpregnant patient.<sup>57</sup> Application of defibrillation and cardioversion shocks to the maternal chest would be expected to pass minimal energy to the fetus and is considered safe in all stages of pregnancy.<sup>29</sup> Defibrillation would be unlikely to cause electric arcing to fetal monitors, and the presence of fetal monitors should not deter providers from the use of rapid defibrillation when indicated.<sup>29</sup> When indicated, defibrillation should be performed in the pregnant patient without hesitation or delay. The risk to the mother in delaying appropriate defibrillation would outweigh any potential concern about defibrillation in the setting of fetal monitors.

### Recommendations

1. The same currently recommended defibrillation protocol should be used in the pregnant patient as in the nonpregnant patient. There is no modification of the recommended application of electric shock during pregnancy<sup>29</sup> (Class I; Level of Evidence C).
2. The patient should be defibrillated with biphasic shock energy of 120 to 200 J (Class I; Level of Evidence B) with subsequent escalation of energy output if the first shock is not effective and the device allows this option.<sup>58</sup>
3. Compressions should be resumed immediately delivery of the electric shock<sup>58</sup> (Class IIa; Level of Evidence C).
4. For in-hospital settings where staff have no ECG rhythm recognition skills or where defibrillators are used infrequently such as in an obstetric unit, the use of an automated external defibrillator may be considered<sup>58</sup> (Class IIb; Level of Evidence C).
5. Anterolateral defibrillator pad placement is recommended as a reasonable default (Class IIa; Level of Evidence C). The lateral pad/paddle should be placed under the breast tissue, an important consideration in the pregnant patient.
6. The use of adhesive shock electrodes is recommended to allow consistent electrode placement (Class IIa; Level of Evidence C).

### *Airway and Breathing*

Hypoxemia develops more rapidly in the pregnant patient compared with the nonpregnant patient; therefore, rapid, high-quality, and effective airway and breathing interventions are essential. As discussed above, a higher partial pressure of oxygen is required to achieve the same maternal oxygen saturation, thus highlighting the importance of ensuring maternal oxygenation and ventilation concurrent with effective chest compressions in the pregnant



patient. As a result, in the 2010 AHA guidelines for CPR and emergency cardiovascular care (ECC), the recommendations for management of cardiac arrest in pregnancy note the importance of early bag-mask ventilation with 100% oxygen.<sup>29</sup> Airway management should always be considered more difficult in the pregnant patient; therefore, appropriate airway algorithms for pregnancy should be instituted. For first responders with minimal airway experience, bag-mask ventilation with 100% oxygen is the most rapid noninvasive strategy to initiate ventilation.<sup>59</sup> The standard initial compression-ventilation ratio of 30:2 will minimize interruptions in chest compressions. Hyperventilation has been shown to decrease the likelihood of survival in nonpregnant arrest victims, particularly when it interrupts chest compressions.<sup>60</sup> Two-handed bag-mask ventilation is more effective than a single-handed technique<sup>61</sup> and should be used as soon as a second provider is available to compress the self-inflating bag. If attempts at mask ventilation do not produce visible chest rise or fog within the face mask, the rescuer should try to reopen the airway and improve the seal of the mask on the patient's face. An oral airway may help relieve airway obstruction in the hypopharynx. Ideally, airway patency should be maintained continuously to optimize oxygen delivery. Obesity, sleep apnea, and airway edema all increase the difficulty of face mask ventilation.<sup>62</sup>

### **BLS Recommendations (Actions Are Simultaneous, Not Sequential)**

1. Rapid notification should be provided to the maternal cardiac arrest response team<sup>29,63–65</sup> (*Class I; Level of Evidence C*).
2. The time when pulselessness was confirmed should be documented<sup>66</sup> (*Class I; Level of Evidence C*).
3. High-quality CPR should be paired with uterine displacement, and a firm backboard should be used<sup>42–45</sup> (*Class I; Level of Evidence C*).
4. Rapid automated defibrillation should be provided whenever it is indicated as appropriate by rhythm analysis<sup>63,65</sup> (*Class I; Level of Evidence C*).
5. Appropriate BLS airway management should be initiated.
  - a. A member of the first responder team should perform bag-mask ventilation with 100% oxygen flowing to the bag at a rate of at least 15 L/min (*Class IIb; Level of Evidence C*).
  - b. Two-handed bag-mask ventilation is preferred (*Class IIa; Level of Evidence C*).
6. Hospitals need to establish first-responder roles that satisfy all of the requirements for BLS, including modifications recommended during pregnancy. A minimum of 4 staff members should respond for BLS resuscitation of the pregnant patient. All hospital staff should be able to fulfill first-responder roles (*Class I; Level of Evidence C*).

### **Advanced Cardiovascular Life Support**

A fast and well-coordinated response to maternal cardiac arrest is important, and the cardiac arrest in pregnancy in-hospital ACLS algorithm should be used as a guide to management (Figure 5). The ACLS maternal cardiac arrest team will continue BLS tasks and perform advanced airway

management, insert an intravenous access above the diaphragm, and administer the usual ACLS drugs and doses when indicated. With the arrival of the obstetric and neonatal teams, preparation for PMCD can begin. The ACLS algorithm includes PMCD as a treatment option for the mother who has not achieved ROSC by 4 minutes after the onset of cardiac arrest and in whom the uterus extends to or above the umbilicus. The cause of the arrest needs to be considered and addressed as necessary.

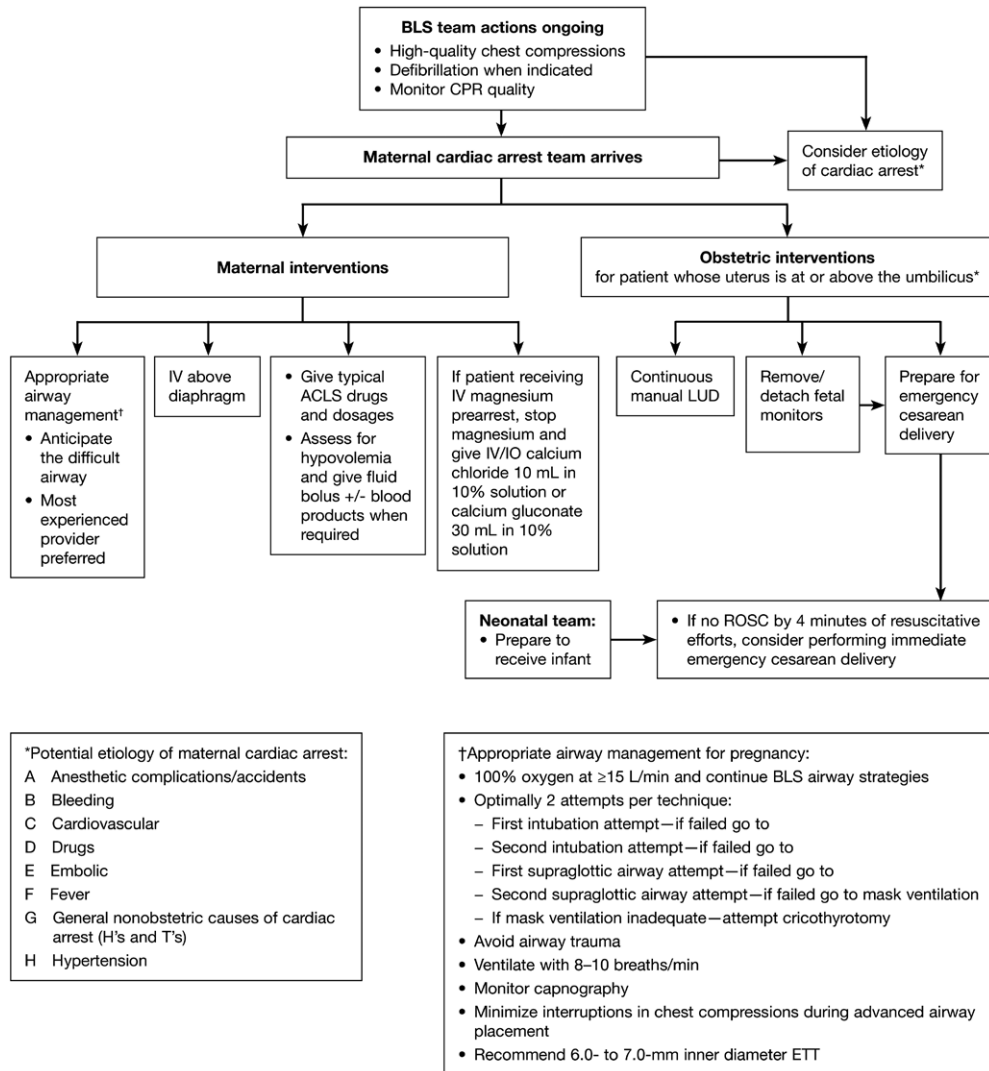
### **The Maternal Cardiac Arrest Team**

Activating and achieving prompt code team response is one of the most fundamental tasks to be completed during maternal cardiac arrest.<sup>29</sup> Each hospital must have a specific method to activate the maternal cardiac arrest team; for example, “maternal code blue” or “code blue maternal” could serve as a universal call to action. Creating 1 “bundled” emergency code call (eg, maternal code blue) to all necessary responders simultaneously may save time, help prevent confusion, and reduce the risk of team members not being notified. The universal call to action should also prompt rescuers to bring the necessary specialized equipment (see section on “Special Equipment Required for a Maternal Cardiac Arrest”) to the scene of the arrest without delay. The composition of the code team must reflect the fact that 2 critically ill patients (mother and fetus) must be resuscitated.

### **Recommendations**

1. There should be 1 call to action that activates the maternal cardiac arrest team, notifies all members, and ensures that specialized equipment is brought to the scene without delay (*Class I; Level of Evidence C*).
2. The maternal cardiac arrest team would ideally be composed of the following<sup>26</sup> (*Class I; Level of Evidence C*):
  - a. An adult resuscitation team (potentially composed of critical care physicians and nurses, and/or emergency physicians and nurses, and/or internal medicine physicians and nurses, and/or other service lines such as general surgery and trauma, with respiratory therapy or equivalent [ie, nurse or physician] and pharmacy representatives according to institutional policy, etc)
  - b. Obstetrics: 1 obstetric nurse, 1 obstetrician
  - c. Anesthesia care providers: obstetric anesthesiologist if available or staff anesthesiologist; anesthesia assistant or certified nurse anesthetist if available
  - d. Neonatology team: 1 nurse, 1 physician, 1 neonatal respiratory therapist or equivalent (ie, nurse or physician)
  - e. In centers without obstetric/neonatology services, it is suggested that the cardiac arrest committee and hospital emergency services discuss contingency plans in the event of maternal cardiac arrest.
3. Leadership during a maternal cardiac arrest is complicated, given the multiple teams involved. Leadership will depend on where the arrest occurs and may be specific to institutional practices. In





**Figure 5.** Cardiac arrest in pregnancy in-hospital advanced cardiovascular life support (ACLS) algorithm. BLS indicates basic life support; CPR, cardiopulmonary resuscitation; ETT, endotracheal tube; IV, intravenous; IO, intraosseous; LUD, left uterine displacement; and ROSC, return of spontaneous circulation.

general, there should be a team leader for adult resuscitation, a team leader for obstetric care, and a team leader for neonatal/fetal care. One approach to deal with multiple subspecialties is for the usual cardiac arrest team leader to delegate leadership for obstetric care, fetal/neonatal care, and airway/ventilatory management. All team leaders must communicate effectively together to make decisions about code management (*Class I; Level of Evidence C*).

#### Special Equipment Required for a Maternal Cardiac Arrest

Special equipment is required for a maternal cardiac arrest. Emergency response committees must ensure that there is a process for delivering this specialized equipment to the code scene without delay if it is not already located on the code cart. Options include either delegating a specific member of the code team to bring the equipment or locating it on the code cart. Specialized equipment should include a PMCD

tray (Table 2) but at a minimum must include a scalpel. In addition, equipment for a difficult airway (Table 3) may be required for the mother. Neonatal resuscitation equipment will be required if the fetus is delivered and viable (Table 4).

#### Breathing and Airway Management in Pregnancy

##### Management of Hypoxia

Current guidelines for the management of cardiac arrest in adults stress that oxygen delivery to vital organs is limited by blood flow during CPR and that chest compressions should not initially be interrupted for ventilation or airway placement. The pregnant patient has a very limited oxygen reserve. Furthermore, it should be noted that cardiac arrest secondary to hypoxia (eg, severe pneumonia, aspiration, amniotic fluid embolism, acute respiratory distress syndrome, narcotic therapy, high spinal block) requires early attention to airway and ventilation. Although delayed endotracheal intubation combined with passive oxygen delivery and minimally interrupted chest compressions has been associated with a better

**Table 2. Recommended Equipment for Perimortem Cesarean Section\***

Equipment Contents of the Emergency Cesarean Delivery Tray
Scalpel with No. 10 blade
Lower end of a Balfour retractor
Pack of sponges
2 Kelly clamps
Needle driver
Russian forceps
Sutures and suture scissors

\*The items listed in this table represent suggestions. The contents should be selected to meet the specific needs, preferences, and skills of the practitioner and healthcare facility.

outcome in witnessed ventricular fibrillation arrest,<sup>67</sup> this is not necessarily the case in the pregnant patient, particularly those with preexisting hypoxia.

## Recommendation

- Hypoxemia should always be considered as a cause of cardiac arrest. Oxygen reserves are lower and the metabolic demands are higher in the pregnant patient compared with the nonpregnant patient; thus, early ventilatory support may be necessary (Class I; Level of Evidence C).**

### Airway Management

It is essential to be familiar with airway management algorithms in maternal cardiac arrest, given the high likelihood of a difficult airway in the pregnant patient.

Because endotracheal intubation is frequently more difficult in pregnant patients compared with the nonpregnant surgical population<sup>68,69</sup> and is best achieved with minimal or

no disruption in chest compressions, any intubation attempts should be undertaken by an experienced laryngoscopist. Forceful laryngoscopy can lead to bleeding and airway edema that interferes with ventilation.<sup>70</sup> Therefore, regardless of provider experience with laryngoscopy, optimally no more than 2 attempts at either direct laryngoscopy or videolaryngoscopy should be made before insertion of a supraglottic airway.<sup>71,72</sup> The glottis in pregnancy is often smaller because of edema; therefore, starting with a smaller endotracheal tube (ETT) may increase the likelihood of successful intubation. Face mask ventilation between laryngoscopic attempts may preserve oxygenation; any difficulty in ventilation indicates the need to avoid further laryngoscopy and to select alternative methods of airway management. Supraglottic airway placement is the preferred rescue strategy to facilitate ventilation after failed intubation.<sup>73</sup> Supraglottic airway devices with an esophageal drain provide access to the stomach to relieve air and stomach contents and may reduce the risk of regurgitation and aspiration pneumonia. Subsequent exchange with a definitive airway with fiberoptic guidance may be considered for women with ROSC. If oxygenation and ventilation are not successful with a supraglottic device or ETT and mask ventilation is impossible, a “cannot intubate, cannot ventilate” situation has occurred. Help (in-house general, trauma, or otolaryngology surgeons) must be called emergently, and the final pathway steps in the difficult airway algorithm must be followed for establishing emergency invasive airway access (eg, percutaneous cricothyroidotomy). Pregnant women and those who are immediately postpartum are at increased risk of regurgitation and aspiration of stomach contents. Despite these concerns, chest compressions, oxygenation, and relief of aortocaval compression are a higher priority than techniques to limit the risk of regurgitation (eg, cricoid pressure, rapid intubation) when caring for the obstetric victim of cardiopulmonary arrest. The 2010 AHA guidelines for CPR and ECC do not recommend the use of cricoid pressure during resuscitation of nonpregnant patients,<sup>74</sup> and there are no data to support its use in the management of pregnant patients during cardiopulmonary arrest. Cricoid pressure may not be effective at preventing aspiration<sup>75</sup> and can impede ventilation and laryngoscopy. If cricoid pressure is used, it should be adjusted or released if ventilation is difficult or the laryngoscopic view is poor. In the event of regurgitation before intubation, suction may be used to remove gastric contents from the oropharynx during ongoing chest compressions.

Continuous capnography should be used if available to assess correct placement of the ETT, the quality of chest compressions, and ROSC. Confirmation of endotracheal placement is complicated by the fact that end-tidal partial pressure of carbon dioxide (PETCO<sub>2</sub>) may decrease to almost zero during cardiac arrest and increase only after the onset of effective CPR. The presence of a decreasing or flat capnographic tracing should prompt the physician leading the code to ensure vigorous chest compressions and LUD, to re-evaluate the location of the airway device, and to consider obstructive causes of cardiopulmonary arrest (ie, massive pulmonary embolism, cardiac tamponade, or pneumothorax). ROSC is more likely when PETCO<sub>2</sub> can be sustained >10 mmHg; an abrupt increase in PETCO<sub>2</sub> by ≈10 mmHg is consistent with ROSC. Findings

**Table 3. Recommended Airway and Breathing Equipment\***

Equipment to Be Used by First Responders	Equipment to Be Used by Experts
Oxygen	Laryngoscope and assorted blades
Bag-valve-mask devices (eg, Ambu Bag with disk valve as opposed to duckbill valve preferred)	Videolaryngoscope
Appropriate size face masks and oral airways	Cuffed tracheal tubes: size 6.0- to 7.0-mm inner diameter with a semirigid stylet and a range of backup sizes available
Stethoscope	Gum elastic bougie
Pulse oximeter	Airway exchange catheter
Qualitative carbon dioxide detector	Supraglottic airways in a range of sizes
Suction device	Flexible fiberoptic intubation equipment
	Equipment suitable for emergency invasive airway access (eg, cricothyrotomy)
	Exhaled carbon dioxide detector

\*The items listed in this table represent suggestions. The contents should be selected to meet the specific needs, preferences, and skills of the practitioner and healthcare facility.

**Table 4. Recommended Neonatal Resuscitation Equipment**

Airway	Breathing	Circulation/Drugs	Miscellaneous
Suction apparatus: Suction bulb Mechanical suction Suction catheters (6F–12F) Meconium aspirator ET intubation supplies: Laryngoscope (blade size: 0 for preterm and 1 for term infants) Extra bulbs and batteries ET tubes (internal diameters: 2.5, 3.0, 3.5, 4.0 mm) Stylets ET-securing device Carbon dioxide detector Tapes and scissors Laryngeal mask airway size 1 (for use when ET intubation is not feasible)	Positive-pressure ventilation: Device: T-piece resuscitator/flow-inflating bag/self-inflating bag with oxygen reservoir (least preferred) Bag sizes 240–750 mL, fitted with pop-off valve Mask sizes 0 and 1 (cushioned preferred) Sources of compressed air and O <sub>2</sub> O <sub>2</sub> blender with a flowmeter (capacity up to 10 L/min) Plastic tubing	IV access: Sterile gloves Antiseptic solution Cord tie Scalpel Umbilical venous catheters (3.5F–5.0F) 3-Way stopcock Suture for securing 24-Gauge IV cannulas (for use if umbilical vessel access not feasible) IO needle (rarely needed) Drugs: Epinephrine 1:10 000 (0.1 mg/mL) Normal saline bags 10% dextrose bags 4.2% sodium bicarbonate (rarely indicated) Saline flushes	Temperature regulation: Heat source (radiant warmer preferred) Warm towels Thermometer (servo-controlled preferred) Clean plastic bag (for extremely premature neonates) Monitoring: Neonatal stethoscope Neonatal cardiac leads Pulse oximeter Neonatal/infant oximeter probes Clock (digital preferred) Other: Firm resuscitation surface (preferably height adjustable) Good light source Nasogastric tubes (6F–10 F) Sterile syringes (1, 3, 5, 20 mL) Clean, sterile gloves Sterile gauzes Bottles to collect blood samples suitable for low-volume blood testing

ET indicates endotracheal; IO, intraosseous; and IV, intravenous.

suggestive of adequate chest compressions, ROSC, or both include a rising PETCO<sub>2</sub> level or levels >10 mmHg.<sup>76–80</sup>

## Recommendations

1. Endotracheal intubation should be performed by an experienced laryngoscopist (*Class I; Level of Evidence C*).
  - a. Starting with an ETT with a 6.0- to 7.0-mm inner diameter is recommended (*Class I; Level of Evidence C*).
  - b. Optimally no more than 2 laryngoscopy attempts should be made (*Class IIa; Level of Evidence C*).
  - c. Supraglottic airway placement is the preferred rescue strategy for failed intubation (*Class I; Level of Evidence C*).
  - d. If attempts at airway control fail and mask ventilation is not possible, current guidelines for emergency invasive airway access should be followed (call for help, obtain equipment).
2. Prolonged intubation attempts should be avoided to prevent deoxygenation, prolonged interruption in chest compressions, airway trauma, and bleeding (*Class I; Level of Evidence C*).
3. Cricoid pressure is not routinely recommended (*Class III; Level of Evidence C*).
4. Continuous waveform capnography, in addition to clinical assessment, is recommended as the most reliable method of confirming and monitoring correct placement of the ETT (*Class I; Level of Evidence C*) and is reasonable to consider in intubated patients to monitor CPR quality, to optimize chest compressions, and to detect ROSC (*Class IIb; Level of Evidence C*). Findings consistent with adequate chest compressions or ROSC include a

rising PETCO<sub>2</sub> level or levels >10 mmHg (*Class IIa; Level of Evidence C*).

5. Interruptions in chest compressions should be minimized during advanced airway placement (*Class I; Level of Evidence C*).

## Arrhythmia-Specific Therapy During Cardiac Arrest

Medical therapy during cardiac arrest is no different in the pregnant patient than in the nonpregnant patient. For patients with refractory (shock-resistant) ventricular fibrillation and tachycardia, the drug of choice is amiodarone; in 2 separate randomized studies, amiodarone has been shown to improve survival to hospital admission compared with standard of care and lidocaine.<sup>81,82</sup> The US Food and Drug Administration categories of fetal risk of medications do not apply in the cardiac arrest scenario because fetal concerns are overshadowed by the arrest outcome.

## Recommendations

1. For refractory (shock-resistant) ventricular fibrillation and tachycardia, amiodarone 300 mg rapid infusion should be administered with 150-mg doses repeated as needed (*Class IIb; Level of Evidence C*).
2. Medication doses do not require alteration to accommodate the physiological changes of pregnancy. Although there are changes in the volume of distribution and clearance of medication during pregnancy, there are very few data to guide changes in current recommendations (*Class IIb; Level of Evidence C*).
3. In the setting of cardiac arrest, no medication should be withheld because of concerns about fetal teratogenicity<sup>83</sup> (*Class IIb; Level of Evidence C*).



4. Physiological changes in pregnancy may affect the pharmacology of medications, but there is no scientific evidence to guide a change in current recommendations. Therefore, the usual drugs and doses are recommended during ACLS (*Class IIb; Level of Evidence C*).

#### *Other Drugs Used During ACLS*

Historically, in the setting of cardiac arrest, vasopressors such as epinephrine and vasopressin have been used with the goal of increasing myocardial and cerebral blood flow and improving patient outcomes. However, as stated in the 2010 AHA guidelines for CPR and ECC,<sup>74</sup> these drugs have not been shown to improve neurologically intact long-term survival.

Epinephrine, an  $\alpha$ -adrenergic receptor stimulant that has been used for many years, has been shown to augment cerebral and myocardial perfusion during cardiac arrest in preclinical studies.<sup>84</sup> However, data in support of clinical efficacy in humans are scant. The first randomized trial evaluating this drug, involving 851 patients assigned to ACLS with drug versus ACLS with no drug, demonstrated an improvement in ROSC with epinephrine but no difference in survival to hospital discharge or long-term survival.<sup>85</sup> These results are consistent with prior observations, and thus, in view of the short-term benefit, the 2010 AHA guidelines for CPR and ECC state that it is reasonable to administer 1 mg IV/IO epinephrine every 3 to 5 minutes (*Class IIb; Level of Evidence A*).<sup>74</sup>

Vasopressin is a nonadrenergic peripheral vasoconstrictor that was studied as an alternative to epinephrine in view of its powerful vasoconstrictive properties. However, in several randomized trials, vasopressin did not prove to be superior to epinephrine, either alone or in combination with epinephrine.<sup>86,87</sup> Because the clinical effect of vasopressin is regarded as equivalent to that of epinephrine, the 2010 AHA guidelines for CPR and ECC recommend 40 U IV/IO vasopressin as an alternative to the first or second dose of epinephrine (*Class IIb; Level of Evidence A*).<sup>74</sup>

A new concept under investigation is the use of a combination of drugs during vasopressor-requiring cardiac arrest. A randomized study of patients with in-hospital cardiac arrest demonstrated that the combination of vasopressin-epinephrine and methylprednisolone during CPR and stress-dose hydrocortisone in postresuscitation shock led to improved survival to hospital discharge compared with epinephrine alone.<sup>88</sup> Despite the promising results, additional studies are needed before recommendations can be made about combined vasopressors.

No data are available comparing the use of different vasopressors during arrest in pregnant patients, but because vasopressin can induce uterine contraction and both agents are considered equivalent in the nonpregnant patient, epinephrine is the preferred agent of the two.<sup>89</sup>

Atropine was removed from the 2010 AHA guidelines for CPR and ECC ACLS cardiac arrest algorithm in view of its lack of efficacy, and it is indicated only for cases of bradycardia.<sup>74</sup>

## Recommendations

1. Administering 1 mg epinephrine IV/IO every 3 to 5 minutes during adult cardiac arrest should be considered. In view of the effects of vasopressin on the uterus and because both agents are considered equivalent, epinephrine should be the preferred agent (*Class IIb; Level of Evidence C*).
2. It is recommended that current ACLS drugs at recommended doses be used without modifications<sup>29</sup> (*Class IIa; Level of Evidence C*).

#### *Fetal Assessment During Cardiac Arrest*

During active CPR, the focus should remain on maternal resuscitation and restoration of maternal pulse and blood pressure with adequate oxygenation. During this time, evaluation of the fetal heart will not be helpful and carries the risk of inhibiting or delaying maternal resuscitation and monitoring. Should the mother achieve ROSC and her condition be stabilized, then fetal heart surveillance may be instituted when deemed appropriate.

## Recommendations

1. Fetal assessment should not be performed during resuscitation (*Class I; Level of Evidence C*).
2. Fetal monitors should be removed or detached as soon as possible to facilitate PMCD without delay or hindrance (*Class I; Level of Evidence C*).

## Delivery

This section is written on the premise that the patient's arrest occurred in an institution that has staff with the expertise to deliver a neonate. PMCD is defined as the birth of the fetus after maternal cardiac arrest, most commonly during resuscitation. Birth is almost always accomplished through cesarean delivery. A review of all published cases of PMCD up to 2010 showed that PMCD led to a clear maternal survival benefit in 19 of 60 cases (31.7%), and there were no cases in which PMCD may have been deleterious to maternal survival.<sup>90</sup>

There may be situations during advanced pregnancy in which noninvasive relief of inferior vena cava compression with manual LUD is not enough to provide a hemodynamic advantage to result in successful resuscitation. This is when PMCD needs to be considered as the definitive means to achieve complete relief of inferior vena cava compression and as a treatment option during ACLS measures for maternal cardiac arrest.

The purpose of timely perimortem delivery is 2-fold. The first is facilitation of resuscitation. If cardiac output has not yet been effectively established, relieving aortocaval compression by emptying the uterus significantly improves resuscitative efforts. Second, and of critical importance, early delivery of the baby, the second patient, is accomplished with a decreased risk of permanent neurological damage from anoxia. In situations in which the mother is nonresuscitable (eg, severe trauma is present), timely delivery of the fetus is essential.

Resuscitation team leaders should activate the protocol for a PMCD as soon as cardiac arrest is identified in a pregnant

woman whose uterus extends to or above the umbilicus.<sup>29</sup> By the time the physician is ready to deliver the baby, standard ACLS should be underway, and immediately reversible causes of cardiac arrest should have been ruled out. When the gravid uterus is large enough to cause maternal hemodynamic changes as a result of aortocaval compression, PMCD should be considered regardless of fetal viability.<sup>29</sup>

### What Defines a Gravid Uterus With the Potential to Cause Aortocaval Compression?

Several factors determine the weight of the gravid uterus, and these additive factors could result in a uterus that is heavy enough or positioned in such a manner to cause aortocaval compression. Determinants of uterine weight include weight of the fetus, the number of fetuses, and the weight of the fluid (ie, polyhydramnios). Other factors that may affect the degree of aortocaval compression include the size of the fetus, the relationship of the fetus to the woman's anatomy, and additional factors such as increased body mass index and morbid obesity.

Unfortunately, published evidence does not adequately address each of these contingencies. However, some general principles can be used to guide recommendations.

A study found that maternal aortocaval compression can occur for singleton pregnancies at >20 weeks of gestational age.<sup>14</sup> One review of PMCD in maternal cardiac arrest before the third trimester concluded that if the fundus extends above the level of the umbilicus, aortocaval compression can occur, and PMCD should be performed regardless of gestational age.<sup>25</sup> Two cases of maternal cardiac arrest in early pregnancy of 13 to 15 weeks were reported in which the mother was resuscitated without PMCD being performed and the pregnancy continued to successful delivery of a live infant at term.<sup>91,92</sup> Not every pregnant woman in cardiac arrest is a candidate for PMCD; the decision depends on whether the gravid uterus is thought to interfere with maternal hemodynamics.

### Why Perform PMCD in Cardiac Arrest?

Several case reports of PMCD during a maternal cardiac arrest resulted in ROSC or improvement in maternal hemodynamic status only after the uterus had been emptied.<sup>93–103</sup> In a case series of 38 PMCDs, 12 of 20 women for whom maternal outcome was recorded had ROSC immediately after delivery.<sup>93</sup> No cases of worsened maternal status after cesarean delivery were reported.<sup>93</sup> The critical point to remember is that both mother and infant may die if the provider cannot restore blood flow to the mother's heart.

### The Importance of Timing With PMCD

The 5-minute window that providers have to determine whether cardiac arrest can be reversed by BLS and ACLS was first described in 1986 and has been perpetuated in specialty guidelines.<sup>93,103a</sup> It was recommended that PMCD should begin at 4 minutes to effect delivery at 5 minutes after failed resuscitative efforts. This time interval was chosen to minimize the risks of neurological damage, which begins to develop after 4 to 6 minutes of anoxic cardiac arrest if there is no ROSC.<sup>104</sup> The rescue team was not required to wait 5 minutes before initiating PMCD, and there are circumstances that support

an earlier start.<sup>24</sup> For instance, in an obvious nonsurvivable injury<sup>30</sup> in which the maternal prognosis is grave and resuscitative efforts appear futile, moving straight to PMCD may be appropriate, especially if the fetus is viable. In the situation of an unwitnessed arrest in which a prolonged period of pulselessness is suspected, the priority of PMCD comes to the forefront.

Many reports document long intervals between a decision for an urgent hysterotomy and actual delivery of the infant, far exceeding the obstetric guideline of 30 minutes for patients not in arrest.<sup>105,106</sup> Very few cases of PMCD fall within the previously recommended 5-minute period.<sup>90,93,94</sup> However, survival of the mother has been reported with PMCD performed up to 15 minutes after the onset of maternal cardiac arrest.<sup>94,107–109</sup> Therefore, if PMCD could not be performed by the 5-minute mark, it was still advisable to prepare to evacuate the uterus while the resuscitation continued. At >24 to 25 weeks of gestation, the best survival rate for the infant occurs when the infant is delivered no more than 5 minutes after the mother's heart stops beating.<sup>104,110–112</sup> At gestational ages >30 weeks, infant survival has been seen even when delivery occurred >5 minutes from the onset of maternal cardiac arrest.<sup>93</sup> In a recent retrospective cohort series, neonatal survival was documented even when delivery occurred up to 30 minutes after the onset of maternal cardiac arrest.<sup>94</sup> A systematic review of all published maternal cardiac arrests occurring before delivery after widespread adoption of resuscitation guidelines (1980–2010) demonstrated a good outcome in most cases; Cerebral Performance Category was assessed to have been 1 or 2 in 78.4% (40 of 51) of mothers and 52.3% (22 of 42) of neonates after the event. In cases undergoing PMCD, the average time elapsing from arrest to delivery was significantly different between surviving (27 of 57) and nonsurviving (30 of 57) mothers (10.0±7.2 minutes [median, 9 minutes; range, 1–37 minutes and 22.6±13.3 minutes [median, 20 minutes; range, 4–60 minutes], respectively;  $P<0.001$ ; 95% confidence interval, 6.9–18.2). The area under the receiver-operating curve for the prediction of maternal death by the time that elapsed from arrest to delivery was 0.827. For neonates, the time elapsing from arrest to delivery was described in only 57 cases and was <4 minutes in only 4 cases. Mean times were 14±11 minutes (median, 10 minutes; range, 1–47 minutes) and 22±13 minutes (median, 20 minutes; range, 4–60 minutes) in surviving and nonsurviving neonates, respectively ( $P=0.016$ ), and the area under the receiver-operating curve for the prediction of neonatal death by the time that elapsed from arrest to delivery was only 0.729, reflecting the wide range of arrest-to-delivery survival times.<sup>90</sup>

### PMCD Technique

The procedure should be performed at the site of the maternal resuscitation. Time should not be wasted moving the patient. Simulation with a manikin of maternal transport to the operating room during cardiac arrest has found that transport increases the time to PMCD.<sup>113</sup> Additionally, time should not be wasted waiting for surgical equipment or doing abdominal preparation. If desired, antiseptic solution may be poured on the maternal abdomen. The only equipment needed to start a PMCD is a scalpel.

Resuscitative efforts should be continued during cesarean delivery, including manual LUD. The position of the rescuer performing the manual LUD will need to accommodate the surgical field to allow access and to prevent injury to the rescuer.

The technique used to perform the PMCD is at the discretion of the physician performing the procedure. Both the vertical incision and the Pfannenstiel incision are acceptable. The vertical incision provides better visualization of the abdomen and pelvis and may prove beneficial in treating the cause of the arrest. The vertical abdominal incision is also considered faster. However, the Pfannenstiel incision may be preferred by a provider who is more comfortable with performing this technique. Because successful PMCD has also been described with the Pfannenstiel incision, it is a reasonable alternative.

During PMCD, the fetus is delivered and given to the neonatal resuscitation team. The placenta is delivered. The uterus should then be quickly wiped clean, and the uterine incision should be closed with a running locking stitch of absorbable suture. The abdomen is closed in the regular fashion. A Foley catheter should be placed at this time if not already present. After the procedure, if maternal resuscitation has been successful, administration of antibiotics and oxytocin may be considered. However, oxytocin should be used with caution because it can precipitate rearrest (see the section on etiology in the online-only Appendix).

Teams find it difficult to perform PMCD in a timely fashion. Therefore, emergency preparedness is important for maternal cardiac arrest. Institutions with limited resources or only 1 staff member available (who, for example, may be involved in an operation when the cardiac arrest is called) should have staff respond as quickly as possible. Response times may be dictated by the reality of staff numbers and availability. Given the rarity of maternal cardiac arrest, it is not reasonable to allocate 2 in-house obstetricians to be on call 24/7 solely for the purpose of responding to a maternal cardiac arrest if the institution otherwise has a more restricted staffing protocol.

## Recommendations

1. During cardiac arrest, if the pregnant woman (with a fundus height at or above the umbilicus) has not achieved ROSC with usual resuscitation measures with manual uterine displacement, it is advisable to prepare to evacuate the uterus while resuscitation continues (*Class I; Level of Evidence C*).
2. Decisions on the optimal timing of a PMCD for both the infant and mother are complex and require consideration of factors such as the cause of the arrest, maternal pathology and cardiac function, fetal gestational age, and resources (ie, may be delayed until qualified staff is available to perform this procedure). Shorter arrest-to-delivery time is associated with better outcome (*Class I; Level of Evidence B*).
3. PMCD should be strongly considered for every mother in whom ROSC has not been achieved after  $\approx 4$  minutes of resuscitative efforts (*Class IIa; Level of Evidence C*).

4. If maternal viability is not possible (through either fatal injury or prolonged pulselessness), the procedure should be started immediately; the team does not have to wait to begin the PMCD (*Class I; Level of Evidence C*).
5. When PMCD is performed, the following are recommended:
  - a. The woman should not be transported to an operating room for PMCD during the management of an in-hospital maternal cardiac arrest (*Class IIa; Level of Evidence B*).
  - b. The team should not wait for surgical equipment to begin the procedure; only a scalpel is required (*Class IIa; Level of Evidence C*).
  - c. The team should not spend time on lengthy antiseptic procedures. Either a very abbreviated antiseptic pour should be performed, or the step should be eliminated entirely (*Class IIa; Level of Evidence C*).
  - d. Continuous manual LUD should be performed throughout the PMCD until the fetus is delivered (*Class IIa; Level of Evidence C*). Care should be taken to avoid injury to the rescuer performing the manual LUD during PMCD.
6. If the uterus is difficult to assess (eg, in the morbidly obese), then determining the size of the uterus may prove difficult. In this situation, PMCD should be considered at the discretion of the obstetrician by using his or her best assessment of the uterus. In these patients, bedside ultrasound may help guide decision making (*Class IIa; Level of Evidence C*).

## Vaginal Delivery During Maternal Cardiac Arrest

Few published cases describe vaginal delivery during a cardiac arrest in pregnancy.<sup>114</sup> Obstetric caregivers involved in an intrapartum cardiac arrest resuscitation may conduct a vaginal examination, provided that CPR is being adequately performed by the medical team. If the cervix is found to be fully dilated and the fetal head is at an appropriately low station, immediate assisted vaginal delivery can be considered. This will allow resuscitation of the fetus and will facilitate the resuscitation of the mother because of the factors discussed above.

## Recommendation

1. Assisted vaginal delivery should be considered when the cervix is dilated and the fetal head is at an appropriately low station (*Class IIb; Level of Evidence C*).

## Neonatal Resuscitation Considerations

### Neonatal Resuscitation Team

It is expected that each maternity hospital will have a designated team for managing unexpected neonatal resuscitations. Because of the high likelihood of delivering a depressed neonate after maternal arrest, the team attending delivery must anticipate and be prepared for an advanced resuscitation. This includes designating a team leader, checking equipment, and



preassigning specific roles to team members. Team composition optimally should include a neonatologist/pediatrician, neonatal nurses, and respiratory therapists who should be familiar with the local neonatal resuscitation algorithms.<sup>115</sup> At least 1 member of the team must be skilled in emergency neonatal endotracheal intubation. In some settings, this may require accepting the urgent assistance of other subspecialty professionals, for example, an anesthesiologist, an otolaryngologist, or emergency physicians.

## Recommendations

1. **The neonatal resuscitation team should be notified of the impending delivery and its circumstances as early as feasible to allow maximum preparatory time (Class I; Level of Evidence C).**
2. **The following critical information should be provided to the neonatal resuscitation team leader: gestational age, number of fetuses, and mode of delivery (Class I; Level of Evidence C).**
3. **In the event of multiple pregnancies, it is recommended that each fetus be resuscitated by a separate resuscitation team (Class I; Level of Evidence C).**

## Neonatal Resuscitation Equipment

PMCD may be performed outside the maternity unit and will require the team to perform resuscitation in a relatively unfamiliar environment that may lack optimal equipment. Each hospital must have prestocked neonatal crash carts available, the locations of which should be clearly marked and known to the neonatal resuscitation team. Alternatively, neonatal resuscitation equipment can be prestocked in easy-to-carry bags that can be taken to the area of need by the resuscitation team on notification of impending delivery. Such carts/bags must be fully stocked, regularly checked, and accessible from all relevant clinical locations of the hospital. A comprehensive list of all equipment deemed necessary for neonatal resuscitation is presented in Table 4.

## EMS Considerations

Maternal cardiac arrest that occurs out of hospital will likely have worse outcomes than cardiac arrest that occurs in hospital.<sup>90</sup> Therefore, a coordinated EMS response to maternal cardiac arrest is of critical importance. If possible, additional prehospital providers should respond to the location of the maternal arrest to ensure that a sufficient number of providers is available to provide BLS (Figure 6) and ACLS care, including LUD. Prehospital providers should not be expected to perform a PMCD; however, transporting the mother in cardiac arrest to a location where PMCD can be performed in a timely manner is essential. Fetal cardiac activity may be slow but present after many minutes of maternal pulselessness.<sup>116,117</sup> As a result, fetal survival can occur in cases when maternal vital signs are lost before arrival in the emergency department and when CPR fails to restore maternal pulses.<sup>118</sup>

Immediate transport of the obviously pregnant patient, identified as the uterus extending to or above the umbilicus,

should be initiated. This is justified because PMCD may be required to achieve ROSC by relieving aortocaval compression, decreased time to PMCD is associated with better fetal outcomes,<sup>90</sup> resources to perform PMCD are usually lacking in the field,<sup>119</sup> and multiple teams will be required to resuscitate the neonate and the mother after PMCD.

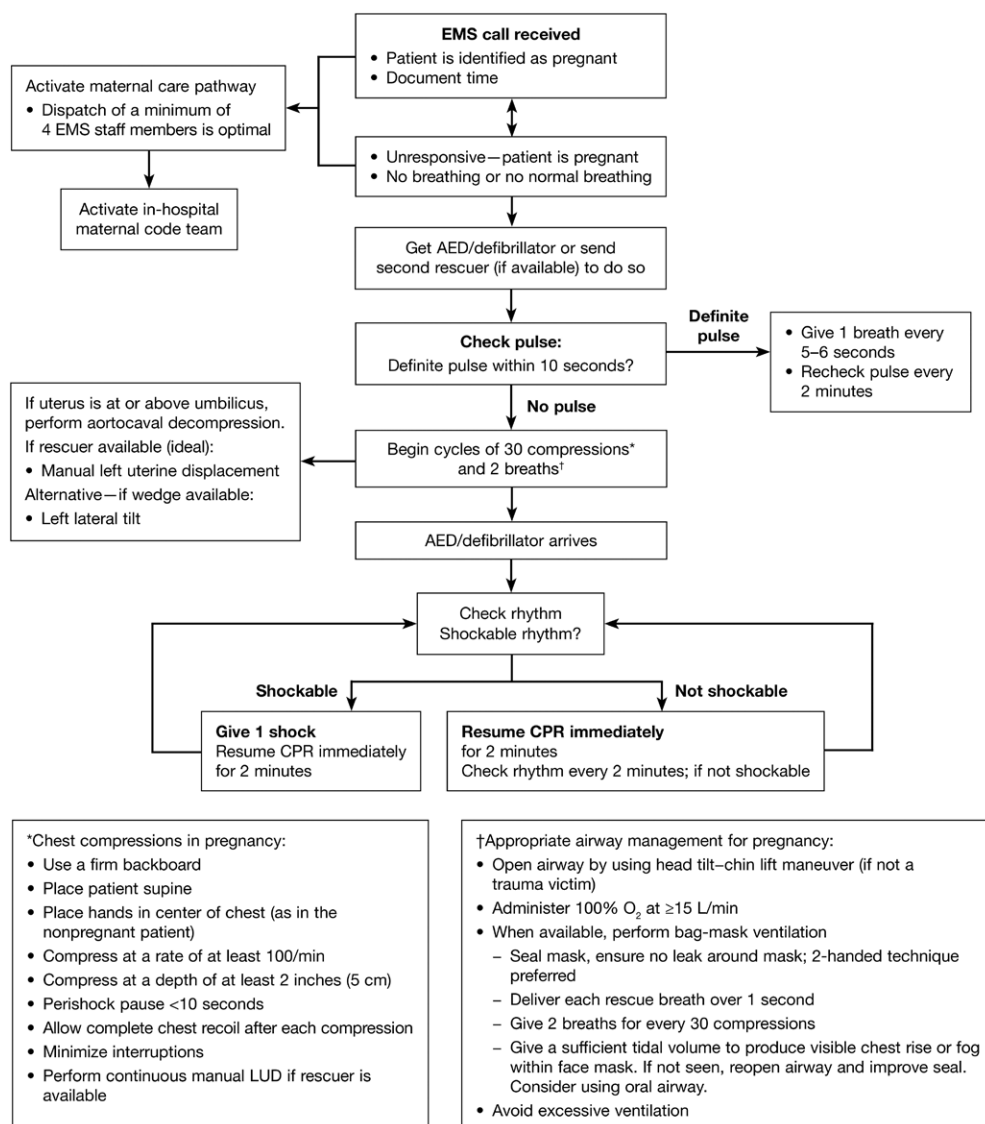
EMS medical directors should identify appropriate receiving hospitals for obviously pregnant patients according to the resources available within the service area. Choices should include whether a specialized obstetric center or a center with a neonatal ICU is preferred over the closest destination. As a result of the geographical restrictions of rural systems, the closest appropriate receiving hospital might be used regardless of the availability of obstetric or neonatal services. For PMCD to be used as a lifesaving procedure, it is extremely time dependent; delays as short as 5 minutes affect fetal survivability. Therefore, transport should be directed toward a center that is prepared to perform PMCD rather than the closest facility, but optimally transport should not be prolonged by >10 minutes to reach a center with more capabilities (eg, neonatal ICU). Although it is possible that prehospital transport will take >5 minutes and the likelihood of PMCD success will therefore be lower, there is still less advantage to transporting a patient to a facility where PMCD cannot be offered. When trauma is the proximate cause of maternal cardiac arrest, resuscitation including PMCD can be performed at a trauma center with early activation of the hospital maternal cardiac arrest team. Bypassing the trauma bay or emergency department to arrive at the operating room is not advisable, given the evidence that CPR quality is impaired during transfer<sup>56</sup> and that procedures do not occur faster in the operating room compared with other settings.<sup>113</sup>

EMS providers in rural or other resource-limited settings may be faced with limited staff and equipment and extended transportation distances to the most appropriate receiving hospitals. EMS systems that provide care in the rural setting should consider these factors during planning and attempt to optimize care through coordinated education and training with first-responder organizations.

EMS responders should use the cardiac arrest in pregnancy out-of-hospital BLS algorithm for healthcare providers as the basis of care during a maternal cardiac arrest (Figure 6).

## Recommendations

1. **If resources are available, EMS response to a maternal cardiac arrest should include the appropriate complement of staff to ensure that BLS and ACLS actions can be performed, including chest compressions, LUD, defibrillation when indicated, and management of the difficult airway (Class I; Level of Evidence C).**
2. **If available, transport should be directed toward a center that is prepared to perform PMCD, but transport should not be prolonged by >10 minutes to reach a center with more capabilities (Class IIb; Level of Evidence C).**



**Figure 6.** Cardiac arrest in pregnancy out-of-hospital basic life support (BLS) algorithm for healthcare providers. AED indicates automated external defibrillator; CPR, cardiopulmonary resuscitation; EMS, emergency medical services; and LUD, left uterine displacement.

**3. EMS and the receiving emergency department must establish optimal communication and an action plan for the transport of a maternal cardiac arrest patient. The emergency department should be able to rapidly mobilize the maternal cardiac arrest team, and specialized equipment should be available from the time the patient arrives in the emergency department (Class I; Level of Evidence C).**

### Cause of the Cardiac Arrest

Similar to the recommendations for adult (nonpregnant) ACLS,<sup>74</sup> an understanding of the importance of diagnosing and treating the underlying cause or aggravating factors of the cardiac arrest is fundamental to the management of cardiac arrest in pregnancy. It is important to consider the cause of the cardiac arrest early in the management algorithm. Specific therapy directed at the cause of the cardiac arrest can be lifesaving. It is important to understand the causes of maternal mortality to have an understanding of the unique pathogenic factors that may have precipitated the

maternal cardiac arrest. The most common causes of maternal cardiac arrest and mortality are listed in Table 5. Caregivers not routinely involved in high-risk pregnancy may not have experience with the presentation or frequency in which specific diagnoses can result in maternal mortality and cardiac arrest. Therefore, the online-only Appendix includes a specific robust chapter that reviews the causes of maternal mortality and highlights important diagnostic and treatment considerations.

### Point-of-Care Instruments

Checklists may help individual responders access temporarily inaccessible cognitive information during periods of intense stress or task saturation. However, the use of checklists during medical emergencies is not consistent, despite the evidence of recurrent cognitive errors on the part of medical providers.<sup>120</sup> Checklists seem particularly well suited to the obstetric domain.<sup>121</sup> One study found that all critical actions for simulated obstetric cardiac arrest were performed only when a cognitive aid reader assisted the team leader.<sup>121</sup> Several groups

**Table 5. Most Common Etiologies of Maternal Arrest and Mortality**

Letter	Cause	Etiology
A	Anesthetic complications	High neuraxial block
		Hypotension
		Loss of airway
		Aspiration
		Respiratory depression
		Local anesthetic systemic toxicity
	Accidents/trauma	Trauma
		Suicide
B	Bleeding	Coagulopathy
		Uterine atony
		Placenta accreta
		Placental abruption
		Placenta previa
		Retained products of conception
		Uterine rupture
		Surgical
		Transfusion reaction
C	Cardiovascular causes	Myocardial infarction
		Aortic dissection
		Cardiomyopathy
		Arrhythmias
		Valve disease
		Congenital heart disease
D	Drugs	Oxytocin
		Magnesium
		Drug error
		Illicit drugs
		Opioids
		Insulin
		Anaphylaxis
E	Embolic causes	Amniotic fluid embolus
		Pulmonary embolus
		Cerebrovascular event
		Venous air embolism
F	Fever	Sepsis
		Infection
G	General	H's and T's
H	Hypertension	Preeclampsia
		Eclampsia
		HELLP syndrome, intracranial bleed

HELLP indicates hemolysis, elevated liver enzymes, and low platelet count.

have recommended and produced obstetric crisis-specific checklists.<sup>26,103a,122</sup> One such checklist for maternal cardiac arrest is provided in Figure 7. These checklists may include, but are not limited to, contact numbers, critical service lines (eg, transfusion services, neonatal/pediatric teams), locations of necessary equipment (eg, scalpel location), and critical steps in care (eg, prepare to make the incision for delivery). The key

factors for optimal use of point-of-care instruments are that teams should be familiar with the content and use of checklists in general and that the checklist should be written specifically for the institution with input from providers who would respond and be involved in rendering care at that institution.

## Recommendation

1. Institutions should create point-of-care checklists to help guide and support critical interventions during obstetric crises (*Class I; Level of Evidence B*).

## Immediate Postarrest Care

It is essential that a multidisciplinary team continue care in the postarrest period. As with all postarrest patients, the pregnant patient who is successfully resuscitated will require thorough assessment, monitoring, and treatment as complications arise. For example, as perfusion improves, bleeding may become a serious issue. If the patient is not delivered, aortocaval compression could precipitate hypotension and rearrest.

## Recommendations

1. If the patient is still pregnant, she should be placed in the full left lateral decubitus position, provided that this does not interfere with additional management issues such as monitoring, airway control, and intravenous access. If the patient is not in full left lateral tilt, manual LUD should be maintained continuously (*Class I; Level of Evidence C*).
2. The patient should be transferred to the ICU unless an operation is required (*Class I; Level of Evidence C*).
3. Optimal pre-event planning should be ensured as discussed above (*Class I; Level of Evidence C*).
4. Multidisciplinary care must continue (*Class I; Level of Evidence C*).
5. The cause of the arrest should continue to be considered and treated accordingly (*Class I; Level of Evidence C*).

## Antiarrhythmic Therapy

Postarrest therapy for recurrent life-threatening arrhythmias includes consideration of placement of an implantable cardioverter-defibrillator or medication therapy in the pregnant patient as in the nonpregnant patient<sup>124</sup> (*Class I; Level of Evidence C*).  $\beta$ -Blockers are often used as first-line therapy for a diversity of arrhythmias; they are generally safe in pregnancy (metoprolol is a preferred  $\beta$ -antagonist used in pregnancy)<sup>125</sup> (*Class IIa; Level of Evidence C*). For long-QT syndrome,  $\beta$ -blockers were found to be effective in reducing the incidence of adverse events and therefore highly recommended during pregnancy and the postpartum period<sup>126,127</sup> (*Class IIa; Level of Evidence C*). In general, for recurrent primary ventricular tachycardia and ventricular fibrillation, amiodarone should be considered (*Class IIb; Level of Evidence C*). Evaluation for reversible causes of cardiac arrhythmias should be routine. Thyroid dysfunction, adverse drug effects, electrolyte disturbances, cardiac ischemia, and heart failure should all be identified and corrected when possible (*Class I; Level of Evidence C*).



<b>Call for help Start CPR</b>	<input type="checkbox"/> Call maternal code blue (Time: _____) <input type="checkbox"/> Backboard (Time: _____) <input type="checkbox"/> IMMEDIATE BLS <input type="checkbox"/> AED/defibrillator <input type="checkbox"/> Maternal airway equipment <input type="checkbox"/> Scalpel/cesarean pack <input type="checkbox"/> Assign timer/documenter <input type="checkbox"/> Document time of cardiac arrest (Time: _____) <input type="checkbox"/> Assign cognitive aid reader/recorder
<b>C Circulation Chest Compressions</b>	<input type="checkbox"/> Left uterine displacement (manual) (Time: _____) <input type="checkbox"/> Hands midsternum <input type="checkbox"/> 100 compressions/min (Time: _____) <input type="checkbox"/> PUSH HARD, PUSH FAST <input type="checkbox"/> Change compressors every 2 minutes <input type="checkbox"/> Obtain IV access above diaphragm (Time: _____)
<b>A Airway</b>	<input type="checkbox"/> Minimize interruptions in chest compressions <input type="checkbox"/> Chin lift/jaw thrust if not trauma victim <input type="checkbox"/> 100% O <sub>2</sub> at ≥15 L/min (Time: _____) <input type="checkbox"/> Use self-inflating bag-mask <input type="checkbox"/> Oral airway or <input type="checkbox"/> Experienced personnel: intubation with 6.0- to 7.0-mm inner diameter ETT or (Time: _____) <input type="checkbox"/> Supraglottic airway (eg, laryngeal mask airway with gastric port) (Time: _____)
<b>B Breathing</b>	<input type="checkbox"/> If not intubated: 30 compressions to 2 breaths <input type="checkbox"/> If intubated: 8–10 breaths/min <input type="checkbox"/> Administer each breath over 1 second
<b>D Defibrillate</b>	<input type="checkbox"/> Pads front and side <input type="checkbox"/> AED: analyze/defibrillate every 2 minutes (Time: _____) <input type="checkbox"/> Immediately resume CPR for 2 minutes <input type="checkbox"/> Prepare for delivery
<b>E Extract Fetus</b>	<input type="checkbox"/> PMCD started (Time: _____) and <input type="checkbox"/> Fetus delivered (Time: _____)

**Figure 7.** Cognitive aid checklist for cardiac arrest in pregnancy. AED indicates automated external defibrillator; BLS, basic life support; CPR, cardiopulmonary resuscitation; ETT, endotracheal tube; IV, intravenous; and PMCD, perimortem cesarean delivery. Modified with permission from Lipman et al.<sup>103a</sup> Copyright © 2014, International Anesthesia Research Society.

## Targeted Temperature Management/Therapeutic Hypothermia

Even when resuscitative efforts are successful in restoring spontaneous circulation, postarrest brain injury often limits the positive outcome for cardiac arrest.<sup>128</sup> One apparent beneficial intervention has been mild postarrest-induced hypothermia, which is based on scientific plausibility and the positive results of 2 randomized, clinical trials published in 2002.<sup>129,130</sup> On the basis of these data, targeted temperature management to 32°C to 34°C (89.6°F–93.2°F) for 12 to 24 hours has been recommended for nonpregnant comatose adult patients with ROSC after out-of-hospital ventricular fibrillation cardiac arrest (*Class I; Level of Evidence B*). There are 2 case reports with favorable maternal and fetal outcomes in which postarrest cooling was instituted in early pregnancy, the fetus was monitored, and emergency cesarean delivery was not necessary.<sup>91,131</sup> There is 1 case report of fetal demise in the setting of targeted temperature management, but in this case, there was a period of unsuccessful resuscitation of 22 minutes before resuscitation by EMS was started.<sup>132</sup> Therefore, data for hypothermia in pregnancy are scant. Pregnancy is thus not an absolute contraindication to targeted temperature management. However, given the lack of data on the use of targeted temperature management after PMCD and the risk of impaired

coagulation during the lowering of systemic temperatures, targeted temperature management may be considered on an individual basis after cardiac arrest in a comatose pregnant patient.

## Recommendations

1. Targeted temperature management should be considered in pregnancy on an individual basis (*Class IIb; Level of Evidence C*).
2. If used in pregnancy, targeted temperature management should follow the same current protocol as for the nonpregnant patient (*Class IIb; Level of Evidence C*).
3. Fetal monitoring should be performed throughout targeted temperature management (*Class I; Level of Evidence C*).

## Fetal Risk of Postresuscitation Intervention

A large number of medications may be used after ROSC is achieved. Unlike in the nonpregnant state, whether medications may adversely affect the fetus must be considered, in addition to the potential compromise caused by circulatory failure, lack of adequate placental perfusion, and impaired oxygen and nutrient exchange between the mother and fetus.

Three major principles guide the decisions made by clinicians at this stage:

1. Maternal well-being is the overriding priority because maternal demise or unfavorable recovery never bodes well for the unborn baby.
2. Embryogenesis is mostly complete by 12 weeks of gestation; hence, even teratogenic drugs (eg, warfarin, phenytoin, corticosteroids) are unlikely to cause malformations if the event occurs after the first trimester.
3. Drugs may cause fetal toxicity rather than teratogenicity in late pregnancy (eg, angiotensin-converting enzyme inhibitors, which can cause fetal renal failure and oligohydramnios).

In general, most therapeutic drugs have a molecular weight of <1000, allowing them to cross the human placenta from the maternal to the fetal circulation. The exceptions are large molecules such as heparin and low-molecular-weight heparin, insulin, and other proteins. However, after 20 weeks of gestation, all biologics that are IgG can cross the placenta by using the Fc transporters. The fact that a drug crosses the placenta is, per se, not a reason for concern because the concentrations of most of these agents do not inflict fetal damage. The risks and benefits of medication use in the postarrest period should be considered on an individual basis.

### Assessment of the Newborn

The majority of neonates delivered by PMCD are likely to require active resuscitation<sup>90</sup>; the severity of perinatal depression and the extent of resuscitation may vary. Management of the neonate after PMCD should follow the most current AHA guidelines.<sup>115</sup>

### Fetal Assessment (If Undelivered)

In cases when maternal cardiac arrest is treated without delivery of the fetus and the pregnancy is considered potentially viable (minimum, 23 weeks of gestation), continuous fetal heart rate monitoring with cardiotocography should be started as soon as feasible after maternal ROSC and continued until clinical recovery of the mother. The goal for such monitoring is to assess for signs of nonreassuring fetal status (fetal tachycardia, bradycardia, loss of heart rate variability, variable or late decelerations) and to monitor for uterine activity.<sup>29,133</sup> Furthermore, because the fetus is considered to be more sensitive to changes in environment, nonreassuring fetal well-being could be the first sign of deterioration of the maternal clinical condition and may signify impending maternal decompensation. The presence of signs of nonreassuring fetal well-being on fetal heart rate monitoring should prompt an urgent obstetric and medical review because an emergency cesarean delivery may be necessary.

### Recommendations

1. Postarrest assessment of the fetus should include continuous fetal heart rate monitoring (*Class I; Level of Evidence C*).
2. Signs of nonreassuring fetal status should prompt a thorough maternal and fetal reassessment (*Class I; Level of Evidence C*).

3. Delivery could be considered if signs of nonreassuring fetal status occur (*Class I; Level of Evidence C*).

### Medical-Legal Considerations

Maternal cardiac arrest and the death of the mother, the fetus, or both are traumatic and usually unexpected events. As highlighted throughout this scientific statement, efforts of all those involved in the care of pregnant women should be directed at prevention, identification of high-risk patients, and referral to specialized care for those at risk for adverse events. However, not all events can be prevented, and if cardiac arrest does occur, EMS, institutions, and individual healthcare team members who would be involved in resuscitative efforts must be prepared. Patient safety is strengthened through this type of proactive approach to pregnancy care. One such example of a system-wide approach to pregnancy care has been shown to result in reduced claims.<sup>134</sup> Once a cardiac arrest has occurred during pregnancy, important steps should be taken to review the care received by the patient to improve systems of care going forward. Implementation of a quality incident notification system has shown that this type of program can help identify avoidable adverse outcomes and can be used to improve practices of care.<sup>134,135,135a</sup> The references highlighted above are useful tools for readers to review and potentially improve their own institutional practices.

### Recommendations

1. All cases of cardiac arrest and maternal near miss should be reviewed by the maternal cardiac arrest committee for the hospital (*Class I; Level of Evidence C*).
2. Identified deficiencies should be corrected (*Class I; Level of Evidence C*).

### Knowledge Translation Strategy

Knowledge translation, also referred to as dissemination and implementation, has been defined by the National Center for the Dissemination of Disability Research as “the collaborative and systematic review, assessment, identification, aggregation, and practical application of high-quality research by key stakeholders (consumers, researchers, practitioners, policy makers) for the purpose of improving the lives of individuals....”<sup>136</sup> This statement represents an important step in the knowledge translation process: the collaborative filtering of information by experts so that only the most valid and useful knowledge is left.<sup>137</sup> Clinicians are often faced with an unmanageable multitude of primary studies or information of variable quality. Comprehensive syntheses presented in statements such as this one provide a trustworthy and applicable aggregation and appraisal of the existing knowledge. This scientific statement is specifically designed to increase the likelihood of translation and uptake by using reviews of the evidence and providing direct practice recommendations.

Reading this statement cannot be where the knowledge translation process ends. An active knowledge translation strategy, which includes multidisciplinary involvement (customized information), barrier assessment, full leadership

commitment and support,<sup>138</sup> and a variety of ongoing dissemination approaches, is crucial to ensure routine use of evidence-based practices.

There is an entire body of literature on various approaches to ensure the routine use of knowledge, all with variable success, depending on the context and intensity with which they are applied. Some approaches that may be specifically pertinent in the case of maternal cardiac arrest include the following:

- Instituting standardized order sets, a prefilled form of evidence-based orders that can be signed by the lead physician so that there is no confusion as to what needs to be done and no time is lost starting from blank orders.
- Developing a program of mock code drills. Lifelike maternal cardiac arrest scenarios are simulated for all staff at regular intervals to make crisis situations feel more commonplace, to decrease fears and anxiety in the team, to improve communication, and to increase familiarity with resuscitation guidelines. This has been shown to directly improve resuscitation skills performance in both the adult<sup>139</sup> and pediatric settings.<sup>140</sup> Recommendations by the Confidential Enquiries Into Maternal and Child Health of the United Kingdom, The Joint Commission, and others emphasize the use of periodic emergency drills that involve both the obstetric and neonatal teams as a way to practice critical communication skills and to identify occult errors in the system.<sup>141–145</sup>
- Building in an audit and feedback mechanism to collect data during resuscitation situations and to provide constructive feedback to the team to identify key areas of success and areas for improvement.
- Holding case debriefing sessions, which are similar to audit and feedback, to provide an opportunity for the team to talk about how the event went, what worked well and what did not work, and to offer a chance for others who may never have been part of a maternal resuscitation to learn from their colleagues' experience.

The key factor to successful knowledge translation is an active, multifaceted approach that attends to the multidisciplinary nature of health care. A unique consideration for maternal cardiac arrest is the relatively low volume of events any one clinician will be involved in treating; this can be detrimental to the impact of knowledge translation efforts. However, strategies such as case discussions and mock drills can be very effective in ensuring that the team is ready when a pregnant patient in cardiac arrest comes through the door.

## Recommendation

1. **All stakeholders/specialties involved in maternal resuscitation should form maternal cardiac arrest committees within each institution to ensure guideline implementation, training, and institution of mock code drills (Class I; Level of Evidence C).**

## Maternal Resuscitation Training

An analysis of simulated maternal cardiac arrests involving participants trained in ACLS suggests that performance during an actual event may be suboptimal.<sup>31</sup> AHA ACLS courses

do not routinely emphasize obstetric-specific interventions. In addition, CPR courses tend to stress knowledge and technical skills over behavioral/communication skill sets.<sup>146,147</sup> The rarity of maternal cardiac arrest<sup>9</sup> implies that participants in CPR courses could benefit from a review of obstetric-specific interventions. Although many obstetric providers are not trained in ACLS, knowledge decay and gaps in fund of information specific to the obstetric domain exist even among those who are.<sup>7,8,148,149</sup>

Maternal cardiac arrest demands a multidisciplinary response that requires unique coordination among teams. Such coordination is predicated on clear and succinct communication.<sup>150</sup> Data from The Joint Commission suggest that communication failures are the root cause of neonatal morbidity and mortality in 70% of cases<sup>142</sup> that occur in the obstetric domain. In addition, in an analysis of preventable maternal mortalities, facility factors contributed significantly to the fatal outcome in 75% of cases.<sup>142a</sup> This suggests that lack of institutional preparedness can decrease or even negate the ability of highly functioning staff to render optimal care. Moreover, ACLS courses cannot hope to address the identification and correction of institutional system issues; this suggests that multidisciplinary maternal cardiac drills are important components of institutional preparedness. Maternally oriented CPR courses are likely more relevant to the learning needs and goals of obstetric staff; these courses have been developed by groups in the United Kingdom and the United States.<sup>94,141,151</sup>

## Recommendations

1. **Periodic multidisciplinary drills may help institutions optimize safety systems (Class IIa; Level of Evidence C).**
2. **Specific courses on maternal resuscitation should be available to staff if not available outside local institutions (Class IIa; Level of Evidence C).**
3. **The future goal should be to have national and international programs in maternal resuscitation (Class I; Level of Evidence C).**

## Future Considerations

The questions remaining unanswered in relation to both treatment and outcomes (both maternal and neonatal) should prompt the establishment of a central registry of cases of maternal near miss and cardiac arrest.<sup>152</sup> Maternal cardiac arrest represents the tip of the iceberg of near-miss maternal complications. Understanding why in some cases the pregnant woman reached a state of arrest may require root-cause analysis.

Multiple issues related to maternal resuscitation remain. Some could be addressed by simple analyses of database information, as mentioned above, for example, whether PMCD improves the rate of ROSC in accordance with the theory of aortocaval decompression, the optimal timing of cesarean delivery for both maternal and neonatal outcomes, and whether these outcomes are as good as those suggested in the most recent literature.

Current guidelines advocate placement of the woman in the full supine position with manual uterine displacement to alleviate aortocaval compression. However, there are sparse data on the impact of the anterior and left lateral displacement



of the heart during pregnancy on the probability of hand placement on the cardiac apex, and data on the effect of manual uterine displacement or pelvic wedging on the position of the heart and upper back are also scant. Finally, both maternal and neonatal long-term neurological status and functional status after resuscitation remain enigmas.

## Recommendations

1. **A central registry of cases of maternal near miss and cardiac arrest with documentation of both process and outcome should be established (Class I; Level of Evidence C).\***
2. **A standardized training course in maternal resuscitation should be developed (Class I; Level of Evidence C).**

## Conclusion

Maternal cardiac arrest is a complex clinical scenario. Resuscitation of the pregnant woman involves multispecialties and complex care decisions. It is unlikely that prospective studies on maternal resuscitation will provide additional data in the future, despite the fact that clinical equipoise remains for most treatments in this situation. Although maternal cardiac arrest is rare, it appears to be increasing in frequency. The number of high-risk women undergoing pregnancy is on the rise, as is the rate of severe complications related to pregnancy (including cardiac arrest).<sup>153</sup> The writing group acknowledges that scientific evidence for management of cardiac arrest in pregnancy is lacking.<sup>154,155</sup> The majority of the writing group's recommendations are Level of Evidence C, which underscores the need for further research. This expert panel of authors has applied

a multispecialty, expert approach to develop these recommendations through experience, previous publication of direct and indirect data, and expert opinion to reach consensus. The writing group recognizes that without an organized approach to maternal cardiac arrest, chaos will likely ensue. Therefore, the development and implementation of the recommendations contained in this document will be beneficial to maternal care. This scientific statement will help healthcare providers be prepared and provide the best possible care for a maternal cardiac arrest. The newly developed in-hospital and out-of-hospital BLS and ACLS algorithms should be the backbone of the response plan to a maternal cardiac arrest. Special attention should be paid to manual LUD, the difficult airway, and appropriate use of PMCD. Lifesaving interventions such as defibrillation and medications should not be withheld in the setting of pregnancy. The healthcare community must be proactively prepared to respond to a maternal cardiac arrest. A maternal cardiac arrest committee must be formed at every institution, and emergency response plans specific to each institution must be developed and implemented. The maternal cardiac arrest committee would link adult resuscitation teams with obstetrics, neonatology, intensive care, anesthesia, the emergency department, and EMS and involve the allied healthcare teams, including nursing, respiratory therapy, social work, and clergy, as available and necessary to implement guidelines and recommendations. Training, mock code drills, and review of cases should become routine. This scientific statement has addressed all aspects of maternal resuscitation: prearrest care, BLS, ACLS, and postarrest care. In addition, the online-only Appendix has a robust chapter on the causes of maternal mortality and cardiac arrest in pregnancy with specific therapies to consider. The statement has also provided readers with resources, point-of-care instruments, and algorithms that will be useful to consider when developing institutional response plans.

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\*For those interested in joining the registry, please email us at [eccscience@heart.org](mailto:eccscience@heart.org).

## Disclosures

## Writing Group Disclosures

Writing Group Member	Employment	Research Grant	Other Research Support	Speakers' Bureau/Honoraria	Expert Witness	Ownership Interest	Consultant/Advisory Board	Other
Farida M. Jeejeebhoy	University of Toronto, William Osler Health System	Rescu Project grant (all funds provided through nonindustry funds)*	None	None	None	None	None	None
Julie Arafeh	Stanford University	None	None	None	None	None	None	None
Clifton W. Callaway	University of Pittsburgh	NHLBI (Research Outcome Consortium)†	None	None	None	None	None	None
Brendan Carvalho	Stanford University	None	None	None	None	None	None	None
Katie N. Dainty	St. Michael's Li Ka Shing Knowledge Institute	None	None	None	None	None	None	None
Sharon Einav	Shaare Zedek Medical Center (Jerusalem, Israel)	Covidien*; Zoll*; Diasorin*; Israel Ministry of Health†; National Institute for Health Policy Research†	None	None	None	Patent on capnography in weaning from mechanical ventilation*	None	European Society of Anaesthesia*; American College of Chest Physicians*
Amish Jain	Mount Sinai Hospital	None	None	None	None	None	None	None
Jose Joglar	UT Southwestern	None	None	None	None	None	None	None
Vern L. Katz	Oregon Health Sciences University	None	None	None	None	None	None	None
Gideon Koren	University of Toronto	Duchesnay Inc†	None	None	None	None	Duchesnay Inc*; Novartis*; Bayer*	None
Stephen E. Lapinsky	University of Toronto	None	None	None	None	None	None	None
Steve Lipman	Stanford University	None	None	None	None	None	None	None
Jill M. Mhyre	University of Arkansas for Medical Sciences	None	None	None	None	None	None	None
Richard L. Page	University of Wisconsin	None	None	None	None	None	None	None
Carole A. Warnes	Mayo Clinic Rochester	None	None	None	None	None	None	None
Rory Windrim	University of Toronto	None	None	None	None	None	None	None
Carolyn M. Zelop	The Valley Hospital	None	None	ACOG annual meeting*	None	None	UpToDate*	None
Staff								
Russell E. Griffin	American Heart Association	None	None	None	None	None	None	None

This table represents the relationships of writing group members that may be perceived as actual or reasonably perceived conflicts of interest as reported on the Disclosure Questionnaire, which all members of the writing group are required to complete and submit. A relationship is considered to be "significant" if (a) the person receives \$10 000 or more during any 12-month period, or 5% or more of the person's gross income; or (b) the person owns 5% or more of the voting stock or share of the entity, or owns \$10 000 or more of the fair market value of the entity. A relationship is considered to be "modest" if it is less than "significant" under the preceding definition.

\*Modest.

†Significant.

## Reviewer Disclosures

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Judith Finn	Curtin University	NHMRC (director of the Australian Resuscitation Outcomes Consortium [Aus-ROC], an NHMRC Center of Research Excellence)*	None	None	None	None	None	None
Kathryn J. Lindley	Washington University in St. Louis	None	None	None	None	None	None	None
Michael R. Sayre	University of Washington	None	None	None	None	None	None	None
John T. Sullivan	Northwestern University	None	None	None	Donohue Brown Mathewson & Smyth*	None	None	None

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\*Modest.

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