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The Society for Obstetric Anesthesia and Perinatology Consensus Statement on the Management of Cardiac Arrest in Pregnancy

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I. Abstract: This consensus statement was commissioned in 2012 by the Board of Directors of the Society for Obstetric Anesthesia and Perinatology to improve maternal resuscitation by providing health care providers critical information (including point-of-care checklists) and operational strategies relevant to maternal cardiac arrest. The recommendations in this statement were designed to address the challenges of an actual event by emphasizing health care provider education, behavioral/communication strategies, latent systems errors, and periodic testing of performance. This statement also expands on, interprets, and discusses controversial aspects of material covered in the American Heart Association 2010 guidelines. (Anesth Analg 2014;118:1003–16)

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II. BACKGROUND, MISSION STATEMENT AND GOALS:

BACKGROUND

- ***What Other Statements or Guidelines Are Available on This Topic?***

Guidelines on maternal cardiopulmonary resuscitation (CPR) are available from the American Heart Association (AHA) 2010 Guidelines on Advanced Cardiac Life Support (ACLS).[1]

- ***Why Was This Consensus Statement Developed?***

This consensus statement was commissioned by the Society for Obstetric Anesthesia and Perinatology to improve maternal resuscitation by providing health care providers critical information and teamwork strategies relevant to maternal cardiac arrest.

- ***How Does This Consensus Statement Differ From Existing Guidelines?***

This consensus statement expands on, interprets, and discusses controversial aspects of material covered in the AHA

2010 guidelines.[2,3] This consensus statement presents relevant up-to-date information, emphasizes critical behavioral skills and contains embedded point-of-care (POC) checklists for use during an actual event to optimize care.

- ***Why Does This Consensus Statement Differ from Existing Guidelines?***

Because there are significant deficiencies in maternal resuscitation knowledge and practice, these recommendations were designed to address the operational reality of a real event by emphasizing team and systems strategies, latent systems errors, and periodic testing of performance.

Mission Statement

The Society for Obstetric Anesthesia and Perinatology's Ad Hoc Committee on Cardiac Arrest in Pregnancy was convened to develop a consensus statement to disseminate information and strategies to improve knowledge of and adherence to maternal cardiac arrest guidelines in order to optimize maternal and neonatal outcomes.

Goals

1. Produce a consensus statement[a] based on the latest available evidence, including existing guidelines,[b] multidisciplinary expert opinion, literature reviews, simulation data and case reports.
2. Clarify critical elements of existing AHA algorithms, review key technical, cognitive, and behavioral interventions during maternal cardiac arrest, and highlight differences in CPR techniques in pregnant women in order to facilitate implementation.
3. Emphasize the importance of immediate preparation for rapid fetal delivery after maternal cardiac arrest without return of spontaneous circulation (ROSC) (goal of incision within 4 minutes and delivery within 5 minutes) and address potential barriers.
4. Produce concise POC checklists to enhance team performance during maternal cardiopulmonary arrest, and encourage institution-specific modifications in order to reflect local operational reality.
5. Provide information to care teams, facilities and organizations that will aid emergency preparedness, continuing education and quality improvement processes.

III. INTRODUCTION

Maternal cardiac arrest during pregnancy challenges health care teams with the simultaneous care of two critically ill patients, mother and unborn baby. These challenges are superimposed upon a general lack of experience in maternal resuscitative measures by obstetric health care teams because cardiac arrest in pregnancy is estimated to occur in < 1:20,000 women.[4] AHA-ACLS courses do not routinely devote significant (or any) resources to teaching obstetric-specific interventions, and such courses tend to stress fund of knowledge and technical skills over important nontechnical (behavioral) skills.[5,6] ACLS course completion rates vary among obstetric health care team providers, and long-term retention of skills is poor.[7] Knowledge decay and knowledge gaps specific to the obstetric patient have been demonstrated even among obstetric health care team providers who have completed CPR courses.[8–11] Obstetric team performance during simulated maternal cardiac arrests suggests that performance during an actual event may be suboptimal.[12] Finally, ACLS courses do not address the identification and correction of institutional systems issues (latent errors in the system), yet facility factors contributed to 75% of fatal outcomes in a report analyzing preventable maternal mortalities.[13]

IV. METHODOLOGY

The current document is intended to complement the 2010 AHA Guidelines Part 12.3, *Cardiac Arrest Associated with Pregnancy and Maternal Cardiac Arrest Algorithm* (Fig. 1)[1] and further develop implementation strategies for recommendations derived from the literature, other interested groups[14] and consensus among committee participants. The committee responsible for creating this document was comprised of physicians and nurses, including experts in resuscitation science and simulation. The disciplines of anesthesiology, cardiology, critical care, emergency medicine, maternal-fetal medicine, neonatology and obstetrics were represented, as well as both the academic and private practice domains. Although this consensus statement is based on the latest (through November 2013) available published material (including simulation data, case reports and series, literature reviews, and expert opinion), the evidence supporting many proposed clinical interventions is limited because of the nature and rarity of maternal arrests.

V. KEY COGNITIVE AND TECHNICAL INTERVENTIONS IN MATERNAL RESUSCITATION

Important note: Although listed numerically, interventions should be performed in parallel as resources permit and certain interventions should occur as soon as possible (e.g., defibrillation if available and indicated).

1. Immediate Basic Life Support (BLS) and Calls for Help

High quality chest compressions should be started immediately to optimize maternal and fetal outcomes, a defibrillator or automated external defibrillator (AED) brought to the scene, the airway opened and ventilation commenced.[1] A "Code OB" (i.e., a clearly identified obstetric-oriented code team response) should be activated immediately, and the Neonatal Team contacted simultaneously. In a study of simulated maternal cardiac arrests, more than 80% of teams were delayed in calling for the Neonatal Team.[12]

2. Chest Compressions

Compressions should be hard (achieving approximately 5-cm depth), fast (100 compressions/min), and

[a]Consensus Statement: A statement of the advised course of action in relation to a particular clinical topic, based on the collective views of a body of experts.[2]

[b]Guidelines" is used in this document to describe recommendations generally complying with the following: "Guidelines are systematically developed recommendations that assist the practitioner and patient in making decisions about health care. These recommendations may be adopted, modified, or rejected according to clinical needs and constraints and are not intended to replace local institutional policies. In addition, practice guidelines are not intended as standards or absolute requirements, and their use cannot guarantee any specific outcome. Practice guidelines are subject to revision as warranted by the evolution of medical knowledge, technology, and practice."[3]

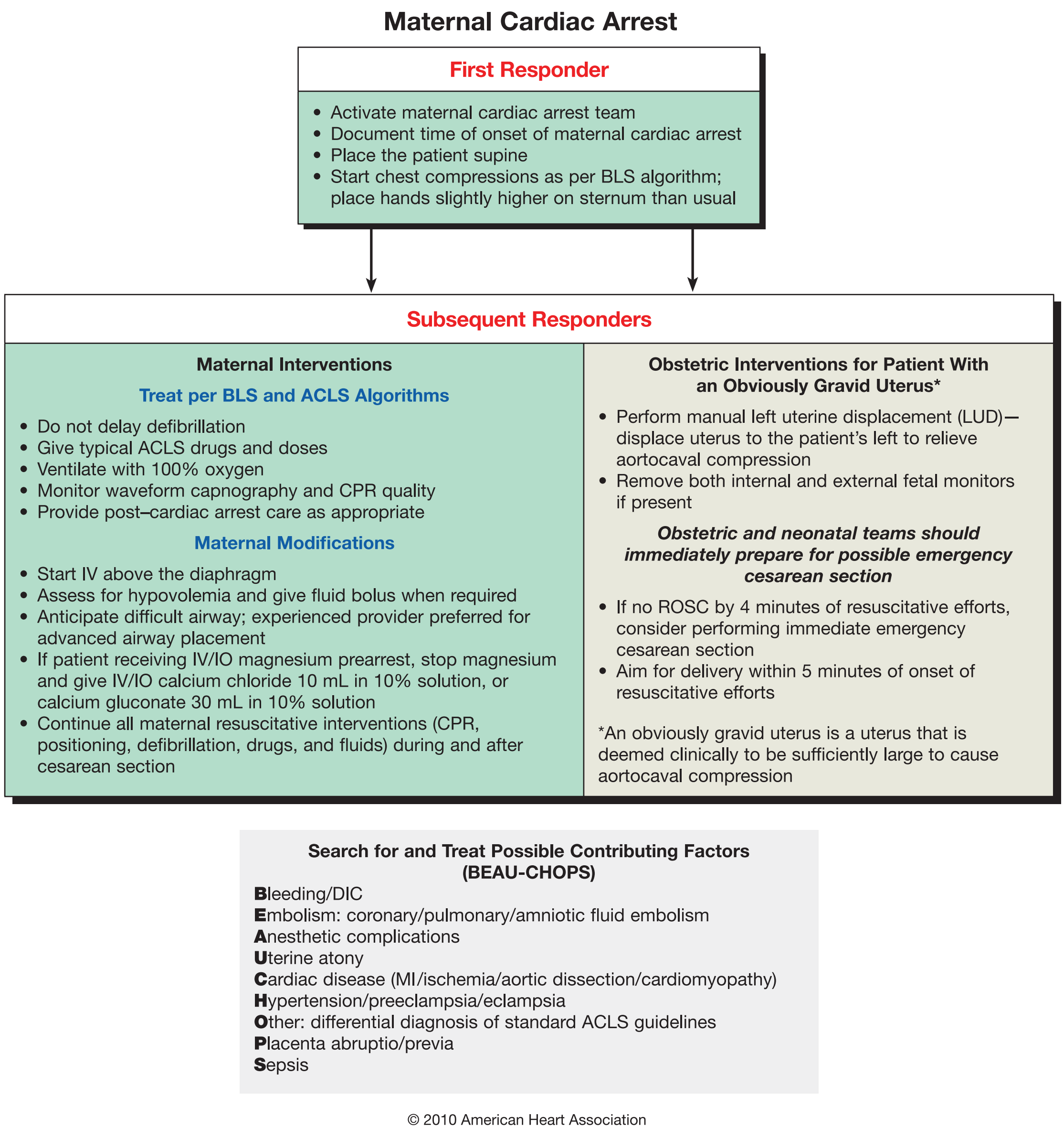

Figure 1. AHA 2010 Maternal Cardiac Arrest Algorithm. Reproduced with permission from American Heart Association (AHA). ACLS = Advanced Cardiac Life Support; BLS = Basic Life Support; CPR = cardiopulmonary resuscitation; DIC = disseminated intravascular coagulopathy; IV/IO = intravenous/interosseous; LUD = left uterine displacement; MI = myocardial infarction; ROSC = Return of spontaneous circulation.

uninterrupted.[14,15] Minimizing interruptions in chest compressions is a key concept taught by the AHA with important consequences for patients who present with shockable rhythms.[15] The "perishock pause" (to check for a shockable rhythm immediately preshock) should be limited to <5 seconds because even brief pauses (>5 seconds) decrease the chance for ROSC.[15,16] To further minimize interruptions in chest compressions, compressions should be resumed immediately after defibrillation. The AHA no longer endorses a pulse check immediately after defibrillation.[14–16] If the patient's trachea is intubated, chest compressions should be performed continuously. If the patient's trachea is not intubated, 30 chest compressions should be followed by 2 breaths in continuous cycles with the goal of providing 100 compressions per minute.[15] Chest compressors should be rotated every two minutes because compressions are physically rigorous and provider fatigue develops rapidly.[15,17–19] For third trimester patients, the AHA recommends that hand placement be 2 to 3 cm higher on the sternum than in nonpregnant individuals,[1] although this recommendation is based on expert consensus only (see Section X, Q. 9).

Continuous capnography measures the partial pressure of carbon dioxide (CO_2) in the expired respiratory gases, and typically displays a graph of end-tidal CO_2 plotted against time. Current AHA-ACLS guidelines recommend capnography as a modality with which to confirm correct endotracheal tube placement and to assess the efficacy of chest compressions.[15] Capnography reflects the quality of chest compressions because it indirectly measures cardiac output in an intubated patient under stable ventilation conditions.[20] During resuscitation, end-tidal CO_2 levels above 10 mm Hg and/or rising end-tidal CO_2 levels suggest adequacy of chest compressions and may be predictive of ROSC.[21–25] Continuous capnography may not yet be readily available in all hospital settings outside the operating room (OR) (e.g., Labor and Delivery units). Attempts to use it should never distract from or interrupt the provision of high-quality chest compressions, nor delay preparations for timely perimortem delivery in the event of no ROSC.

3. Patient Position and Left Uterine Displacement

Left uterine displacement (LUD) is recommended if the uterus is palpable or visible at or above the umbilicus[1] in order to minimize the adverse effects of vena caval compression by the gravid uterus on venous return and cardiac output.[26] However, caval compression may occur even earlier in pregnancy.[27] The provision of LUD should be based on individual circumstances such as multiple gestation, polyhydramnios, or other conditions in which vena caval obstruction may be a relevant concern, even if the gestational age is <20 weeks. The cardiac output produced from chest compressions is optimized when the arrested parturient is placed on a firm surface (e.g., a backboard) in the supine position with manual LUD.[1,28–30] Manual LUD is optimally performed using two hands from the left side of the patient.[1] The designated provider must pull leftward and upward (toward the ceiling); if downward force is inadvertently applied, inferior vena caval compression may worsen. If it is not possible to perform manual LUD from the left, it may be applied from the right side of the patient by pushing away and toward the ceiling with one or both hands, although this approach may be technically more difficult to perform adequately.[1] Left lateral tilt of the patient to a full 30 degrees (i.e., pelvic tilt) can also be used to provide LUD, but this position may make the provision of adequate chest compressions more challenging as the force transmitted to the chest wall is reduced.[1,31–33] In a study of simulated maternal cardiac arrest, initiation of LUD was often neglected.[12]

4. Defibrillation

"The AHA strongly recommends performing CPR while a defibrillator or AED is readied for use and while charging for all patients in cardiac arrest."[15] Defibrillation should be performed for shockable rhythms as soon as it is available. In sudden cardiac arrest with ventricular fibrillation, the earlier defibrillation occurs the greater the chance of successful defibrillation and ROSC with continuing chest compressions. Defibrillation is safe for the fetus in the setting of maternal cardiac arrest and energy requirements for adult defibrillation are the same in pregnancy and do not need to be altered.[1] The AHA (and others) have analyzed the use of AEDs in comparison to manual defibrillators: "Despite limited evidence, AEDs may be considered for the hospital setting as a way to facilitate early defibrillation (a goal of shock delivery <3 minutes from collapse), especially in areas where staff have no rhythm recognition skills or defibrillators are used infrequently."[15,34] In most obstetric settings, use of an AED device (or the AED mode on a defibrillator) is the most practical approach for rapid defibrillation. Ideally, when an AED is used, the device should have a user override function to allow an experienced provider to deliver the shock without waiting for the prescribed built-in analytical algorithm.

The benefits of using pads rather than paddles include provider safety (the ability to step away from the patient during shock), decreased potential for task saturation (it is unnecessary to hold the pads once they are placed), and the continuous display of electrical cardiac activity. If pads are placed in the anterior and posterior positions, they can be used to both defibrillate and pace. If maternal CPR is ongoing and a fetal scalp electrode (FSE) is in place to monitor the fetal heart rate, it is reasonable to disconnect it from the power source before shock. If external fetal monitors are being used, it is reasonable to remove them from the patient before shock and in preparation for cesarean delivery. However, theoretic concerns of electrical burn to the mother and/or fetus should never delay defibrillation. The key point to remember in the setting of maternal cardiac arrest is that fetal monitoring is not necessary to guide management and may distract staff from or delay the provision of maternal CPR and fetal delivery (see Section X, Q. 7).

5. Airway Management and Ventilation

A simplified airway algorithm is shown in Fig. 2. First-responders without advanced airway experience must use strategies to oxygenate the patient (e.g., jaw thrust, oral airway, bag-mask ventilation). Oral airways are preferred over nasal airways in pregnant patients because of the potential for epistaxis. Repeated airway manipulations should be minimized to avoid airway trauma and interruptions in

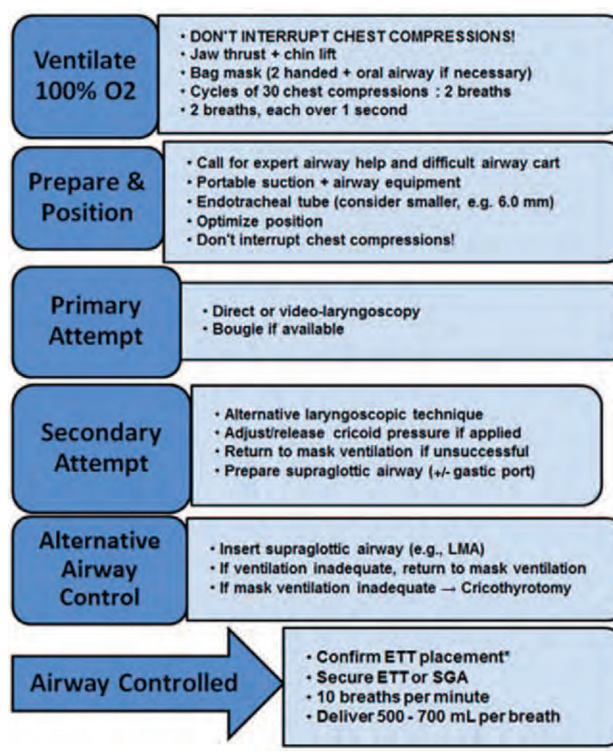

Figure 2. An example of a simplified airway algorithm for airway control during maternal cardiac arrest. This checklist can be modified based on locally available equipment and practice. Abbreviations: ETT = endotracheal tube; LMA = laryngeal mask airway; mL = milliliters; mm = millimeters; PPV = positive pressure ventilation; SGA = supraglottic airway. All the checklists contained in this document may be modified, printed, laminated, and posted on the code cart or in other areas.

chest compressions. To avoid interference with chest compressions in the nonintubated patient, AHA guidelines emphasize two 500–700 mL tidal volumes (each delivered over one second for two seconds total time) alternating with 30 compressions.[15] Personnel with experience in advanced airway management should perform laryngoscopy. Care must be taken to avoid fixation errors associated with one specific technique of airway management (e.g., "must intubate"),[6] and alternative airway control strategies such as supraglottic airway devices (e.g., laryngeal mask airways) should be considered. Although pregnant patients are at risk for aspiration,[35,36] oxygenation and ventilation must always remain the primary objectives and take priority over aspiration prevention strategies. Evidence suggests that cricoid pressure may not be effective at preventing aspiration,[37–39] and that it can impede ventilation and laryngoscopy. AHA 2010 guidelines do not recommend cricoid pressure in nonpregnant patients[15] and there is no specific information to support its use in pregnant patients. If cricoid pressure is used, it should be released or adjusted if ventilation is difficult or the view during laryngoscopy is poor.

6. Intravenous Access

Intravenous access is essential for rapid intravascular volume repletion and administration of resuscitation drugs. During massive obstetric hemorrhage, critical interventions include multiple sites of large-gauge vascular access, a massive transfusion protocol, a fluid-warming rapid infuser, subhepatic manual compression of the aorta, and the timely notification and involvement of gynecologic oncologists, vascular surgeons, and/or trauma surgeons.[40] Each institution should develop an algorithm to be used in the event of difficult peripheral IV access, including alternatives such as intraosseous access in the proximal humerus, or ultrasound-assisted peripheral or central venous access. Obtaining IV or intraosseous access above the diaphragm is recommended to avoid the potentially deleterious effects of vena caval compression, which could increase the time required for fluids or administered drugs to reach the heart or even prevent their circulation altogether.[1,15]

7. Resuscitation and Other Drugs

Resuscitation drugs should be administered as per current AHA guidelines. None of these drugs (e.g., epinephrine, amiodarone, etc) should be considered contraindicated during maternal cardiac arrest.[1] Although physiologic changes of pregnancy (increases in intravascular volume, decreases in protein binding, and increases in glomerular filtration rate) may alter the volume of distribution and clearance of drugs, these changes are likely to be irrelevant in the low or no-flow state of maternal cardiac arrest. If local anesthetic-induced cardiac arrest is suspected, lipid emulsion may be administered as an adjunctive therapy as in the nonpregnant patient.[33,41] Because there are no data on which to base dosage of lipid emulsion or other resuscitative drugs in the pregnant patient, the usual doses used in nonpregnant individuals should be administered (see Section X, Q. 10.[1,42,43] In addition to its uterotonic effect, oxytocin is a systemic vasodilator and a negative inotrope and therefore may precipitate cardiovascular collapse if administered in large (5–10 international units) bolus doses.[44,45] Although beyond the scope of this Consensus Statement, staff should be familiar with contraindications to and side effects of commonly used uterotonic drugs.

8. Perimortem Cesarean or Operative Vaginal Delivery

Current guidelines and case reviews support rapid delivery of the fetus in the setting of maternal cardiac arrest unresponsive to CPR,[1,14,46–50] yet one-third of these patients remain undelivered at the time of death.[51] When vaginal delivery is not immediately possible, perimortem cesarean delivery (PMCD) is required in order to improve the chance of ROSC and maternal and fetal survival.[1,14,46–50] Delivery should be performed as soon as possible if ROSC has not occurred within minutes of the start of the cardiac arrest. Teams should continue CPR throughout and strive to make incision at 4 minutes in order to effect fetal delivery at 5 minutes after the start of cardiac arrest. The team should be actively preparing for expedited delivery as soon as the arrest is confirmed.[1,14] The decision to do an operative vaginal delivery instead of PMCD should be at the discretion of the obstetrician.

Proposed mechanisms for the benefits of PMCD include immediate relief of vena caval obstruction with improved venous return and cardiac output, decreased oxygen demand, and improved pulmonary mechanics. Although definitive evidence is lacking (and may be unobtainable), numerous reports describe ROSC or improvement in hemodynamics after delivery has occurred.[46–50,52–69] In a series of 38 cases of PMCD reported in 2005, 12 of 20 women for whom maternal hemodynamic outcome was recorded had ROSC immediately after delivery; in no cases did PMCD worsen maternal status.[48] In a 2012 review of 91 published cases of maternal cardiac arrests, 54% of mothers survived to hospital discharge.[50] PMCD was performed in 76 (87%) viable pregnancies. Although two-thirds of the arrests occurred in highly monitored areas of the hospital and 89% of the arrests were witnessed, only 7% of patients were delivered within 5 minutes. PMCD was determined to have benefited the mother in 32% of cases and to have caused no harm in any of the others. In this series, in-hospital arrest and PMCD within 10 minutes were associated with better maternal outcomes.[50]

Although the AHA and others propose aiming for delivery within 5 minutes of the onset of maternal arrest without ROSC,[1,14,47–49] it is difficult to achieve delivery within such a timeframe. In the 2012 review, only 4 of 76 women were delivered within 5 minutes.[50] Under the ideal conditions that prevailed in a study of simulated maternal arrests, only 14% of teams randomized to transport to the OR for PMCD made incision within 5 minutes.[70] Only 57% of teams randomized to perform PMCD at the site of arrest without transport made incision within 5 minutes.[70]

Neonatal survival may be optimized (if past viability at 24–25 weeks' gestation) when the fetus is delivered within 5 minutes of maternal arrest.[47,71] Although maternal and neonatal survival have been reported when even longer intervals from arrest until ROSC occurred, prolonged low flow states increase the risk of permanent maternal and neonatal disabilities or demise.[31,47–51,71,72]

In the absence of an obstetrician or surgeon or in circumstances such as an out-of-hospital arrest, it may be difficult or impossible to perform immediate delivery. However, in most situations, the timing of delivery remains more critical than the location of delivery. When maternal cardiac arrest occurs in the Labor and Delivery unit, Emergency Medicine Department or Intensive Care Unit (ICU), transporting the arrested patient to the OR for delivery is not recommended. Patient transport distracts rescuers from the core tasks of resuscitation, interferes with high-quality, continuous chest compressions, and delays delivery.[70,73] Based on reviews of maternal arrests in the literature, simulation studies, and anecdotal reports, the Committee strongly recommends performing PMCD (or operative vaginal delivery) at the site of arrest rather than moving to the nearest OR.

If PMCD is performed and results in ROSC, transport to the nearest OR can occur after delivery when patient condition permits. Similarly, if ROSC occurs without prior delivery, transport to the OR can be undertaken, with the team ready to perform immediate cesarean delivery should the condition of the mother or fetus deteriorate. Subsequent transfer to the ICU for continuing care should take place when the clinical situation permits. While sterile preparation of the skin is not a priority during PMCD, teams electing to perform it should do so within the first few minutes of the arrest. Early sterile preparation may serve as a visual prompt to all staff present that PMCD is impending, and help to avoid potential delays to incision by allowing the solution time to dry.

VI. KEY BEHAVIORAL INTERVENTIONS IN MATERNAL RESUSCITATION

1. Organization of Response Teams

Immediate and effective communication that an emergency is occurring is critically important during maternal cardiac arrest because of the number of teams that must be rapidly mobilized and coordinated. Key calls often missed in the opening moments of simulated maternal cardiac arrest include those to the neonatal team and for equipment necessary for emergency delivery (i.e., scalpel).[12,70] We recommend an emergency call system (with backup) in which all providers in the maternal/neonatal resuscitation teams are activated immediately and simultaneously ("Code OB" is one suggested approach). The service lines comprising the emergency response team should be listed at the POC (i.e., the emergency call button or phone) and with hospital telephone operators.

All response team members should be familiar with the location of critical equipment (e.g., scalpel, umbilical cord clamps, maternal and neonatal resuscitation supplies) and be aware of the fastest routes to the Labor and Delivery Unit, Emergency Medicine Department, and all ICUs. In many institutions, security on the Labor and Delivery unit is enhanced, including limited elevator access and locked stairway and door entry/exit points. The requirements for entry should be reviewed, electronic cards or keypad sequences distributed, and barriers to emergency access evaluated. All these systems should be tested in routine and periodic obstetric emergency drills and local protocols developed or revised to address deficiencies.

2. Communication Within the Team During Resuscitation

"Open-air" commands (commands not directed at specific individuals) are common communication errors during crises. "Failure to close the loop" (i.e., not verbally acknowledging, performing, and verbally confirming completion of an order) may result in redundancy of effort, global task saturation, and delays in critical interventions.[74] Periodic multidisciplinary drills allow teams to learn, practice and refine critical communication skills in a safe environment. The use of brief, periodic "time-outs" during the provision of CPR may help to optimally coordinate ongoing care during the emergency. During the brief time-out, the leader or timer/documenter should succinctly review the working diagnosis, the interventions that have been completed, and the goals and priorities moving forward. Chest compressions should not be interrupted.

3. Workload Delegation and Assignment of Roles

During the initial minutes of an emergency, there are likely more interventions that need to be completed than individuals present to complete them. Data from a study of simulated maternal arrests indicated that poor workload delegation was a recurrent error (e.g., several nurses involved in preparing the abdomen when one would suffice).[12] Key roles such as timer/documenter, airway assistant, a second person to rotate performance of chest compressions, or a staff person dedicated to performing LUD, and key interventions such as timely defibrillation, backboard insertion, and LUD were often neglected.[12] One approach to this problem is for institutions to define standard roles for staff to be assigned during emergencies. Each specific role can be associated with certain tasks and responsibilities and practiced during multidisciplinary drills.

4. Leadership

During maternal cardiac arrest, two individuals (mother and unborn baby) require the coordinated interventions of multiple care teams (nursing, obstetric, neonatal, anesthesia, and the adult code team). As a result, maternal cardiac arrests may require shared decision-making. Communication and coordination among the various teams can have major impacts on patient outcomes.[74,75]

The code leader ideally should be an individual with knowledge of the management of pregnant patients. The code leader should not be task saturated, and should be able to direct interventions, communicate effectively, and periodically reassess management goals and outcomes. A POC checklist emphasizing key tasks (Table 1) should be immediately available (e.g. attached to the resuscitation cart). The code leader should designate a team member to serve as the "reader" during the maternal arrest so that interventions from the checklist can be read aloud and cross-checked.[76–79]

VII. IDENTIFYING CAUSES OF A MATERNAL CARDIAC ARREST

The AHA has developed a mnemonic, BEAUCHOPS, (Fig. 1) to help memorize contributing causes in the event of a maternal cardiac arrest.[1] However, any mnemonic that facilitates remembering potential causes is acceptable and

Table 1. Checklist of Key Tasks During the First Minutes of In-House Maternal Cardiac Arrest

Call for help!	☐ Call "OB Code"
Start CPR	☐ Call neonatal team
	☐ AED/defibrillator
	☐ IMMEDIATE BLS
	☐ Adult code cart
	☐ Adult airway equipment
	☐ Backboard
	☐ Scalpel/Cesarean pack
	☐ Assign timer/documenter
C Circulation	☐ Left uterine displacement (manual)
Chest compressions	☐ Hands mid-sternum
	☐ 100 compressions/min
	☐ PUSH HARD! PUSH FAST!
	☐ Change compressors every 2 min
	☐ Obtain IV access above diaphragm
A Airway	☐ Chin lift/jaw thrust
	☐ 100% O_2 at 10–15 L/min
	☐ Use self-inflating bag mask
	☐ Oral airway or
	☐ Experienced personnel: Intubation with 6–7.0 ETT or
	☐ Supraglottic airway (e.g., LMA)
	☐ Do not interrupt chest compressions!
B Breathing	☐ If not intubated: 30 compressions to 2 breaths
	☐ If intubated: 10 breaths per min (500–700 mL per breath)
	☐ Administer each breath over 1 s
D Defibrillate	☐ Pads front and back
	☐ Use AED or Analyze/defibrillate every 2 min
	☐ Immediately resume CPR for 2 min
	☐ Prepare for delivery
E Extract FETUS	☐ Aim for incision by 4 min
	☐ Aim for fetal delivery by 5 min

Important note: Although listed serially, interventions should be performed in parallel as resources permit and certain interventions should occur as soon as possible (e.g. defibrillation if available and indicated).

Adapted with permission from OBSim, a multidisciplinary obstetric crisis team-training program, and Obstetric Basic Life Support (OBLS), Center for Advanced Pediatric & Perinatal Education [CAPE], Lucile Packard Children's Hospital, Stanford University.

CPR = Cardiopulmonary Resuscitation, BLS = Basic Life Support, AED = Automated External Defibrillator, IV = intravenous, LMA = Laryngeal Mask Airway, O_2 = Oxygen, ETT = Endotracheal tube; min = minute; s = second; L = liter; mL = milliliters.

can be used. A simple checklist for contributing causes such as that outlined in Table 2 should be immediately available for reference (e.g., attached to the resuscitation cart). A 2012 comprehensive review article on maternal cardiac arrest found that better outcomes resulted when the arrest occurred in highly monitored clinical settings.[50] Thus, any patient in whom there is concern for impending cardiopulmonary decompensation should be identified as "high risk" and admitted to an appropriate clinical setting if she is not already located there.

VIII. POSTCARDIAC ARREST CARE

The AHA guidelines for postresuscitation care should be followed to prevent secondary deterioration in maternal condition.[15] In patients who are status post-delivery and remain refractory to resuscitation interventions (no ROSC), the use of mechanical circulatory support such as venoarterial extracorporeal membrane oxygenation or cardiac bypass may be appropriate as a bridging intervention if

Table 2. Checklist of Potential Contributing Factors to Maternal Cardiac Arrest

A	Anesthetic complications (high neuraxial block, loss of airway, aspiration, respiratory depression, hypotension, local anesthetic systemic toxicity)
B	Bleeding* (coagulopathy, uterine atony, placenta accreta, placental abruption, placenta previa, uterine rupture, trauma, surgical, transfusion reaction)
C	Cardiovascular causes (cardiomyopathy, myocardial infarction, aortic dissection, arrhythmias)
D	Drugs (anaphylaxis; illicit; drug error; magnesium, opioid, insulin, or oxytocin overdose)
E	Embolic (pulmonary embolus, amniotic fluid [AFE], air)
F	Fever* (infection, sepsis)
G	General nonobstetric causes of cardiac arrest (H's and T's)†
H	Hypertension* (preeclampsia/eclampsia/HELLP, intracranial bleed)

Most likely causes: Cardiac, hemorrhage and AFE. Suspect amniotic fluid embolus (AFE) with any sudden maternal cardiac arrest, particularly when accompanied by bleeding.

*Often diagnosis is apparent or predicted from pre-arrest condition

†The H's and T's: Hypoxia, Hypovolemia, Hyper/hypokalemia, Hypo/Hyperthermia, Hydrogen ions (Acidosis), Hypoglycemia, and Tension pneumothorax, Tamponade, Toxins, Thromboembolism, Thrombosis (Myocardial infarction), Trauma. [American Heart Association: Advanced Cardiovascular Life Support Provider Manual, First American Heart Association Printing, 2011.]

available.[80,81] Correcting reversible etiologies of arrest in an otherwise healthy parturient can lead to rapid return of cardiac output after resuscitation and delivery. As a result, health care teams may need to manage uterine bleeding in the post-arrest patient. The return of cardiac output may also result in maternal awareness, necessitating the provision of analgesic or amnestic medications. Maternal transfer to an ICU should be accomplished as soon as possible after PMCD is completed. Skilled intensivist and nursing care are essential regardless of the patient's location and should be directed according to the suspected cause of the arrest.

In most patients, delivery will relieve vena caval compression, and the supine position will then optimize the quality of chest compressions and facilitate access for laparotomy, surgical repair and vascular access placement. If uterine distension or an obese abdominal wall continues to obstruct venous return to the heart, LUD or abdominal wall displacement should be maintained. After ROSC in an undelivered patient, left uterine displacement should be maintained to optimize uterine blood flow and venous return and thus minimize the risk of recurrent cardiac arrest.

Therapeutic hypothermia is recommended in comatose nonpregnant patients after cardiac arrest to decrease the impact of injury to cardiac or neuronal tissue.[15,82] Therapeutic hypothermia has been reported in several women who had a cardiac arrest during the first half of pregnancy.[83–85] No adverse fetal effects resulted, except in one case in which multiple other complications were present that could have explained or contributed to the stillbirth.[85] Hypothermia has been used during pregnancy for maternal neurosurgical and cardiac procedures;[86,87] however, we could find no reports regarding the use of therapeutic hypothermia after cardiac arrest in undelivered women closer to term. Based on recommendations for nonpregnant patients after cardiac arrest, we believe that therapeutic hypothermia for maternal benefit should be strongly considered after cardiac arrest in obstetric or postpartum patients for similar indications as in the general population.[82] However, it must be acknowledged that the fetal effects of maternal hypothermia in this circumstance remain largely unknown. Because fetal bradycardia has been reported during maternal hypothermia, continuous electronic fetal monitoring should be used to guide obstetric management.[88] Caution must also be exercised when using hypothermia in a setting of maternal hemorrhage and coagulopathy, because hypothermia may impair hemostasis and worsen or precipitate further blood loss.[89]

IX. QUALITY IMPROVEMENT AND IMPLEMENTATION STRATEGIES

Multidisciplinary drills help to open and maintain lines of communication among the various services involved in the response to a maternal cardiac arrest. Such dialogue is necessary for advance preparation before an actual event occurs. Regularly scheduled drills help familiarize obstetric staff with specific roles, responsibilities, resuscitation algorithms, and optimal communication techniques during emergencies. Unannounced drills help test the emergency call system and allow the response times from the necessary services to be measured. Unannounced drills also allow experienced teams to practice under intense time pressure with no forewarning (e.g., for "stress inoculation"). Ideally, all drills should be timed and followed by a debriefing session to collectively analyze behavioral, cognitive, and technical skill-sets. Drills conducted at the POC (in situ drills) help to identify systems issues that may then be corrected before an actual emergency. Developing strategies to mitigate potential systems issues should occur in all departments that may receive obstetric patients (e.g., Labor and Delivery, Emergency Medicine Department, ICU, Radiology). All these locations should be supplied with or have access to mobile carts containing equipment for maternal and neonatal resuscitation (Table 3).

The actions of one provider or any single intervention rarely result in a positive or negative outcome in the event of maternal cardiopulmonary arrest; rather, it is the global performance of the resuscitation team and institutional preparedness for rare, critical events. While creating a portable emergency cesarean delivery instrument set (Table 3) or a locally relevant airway algorithm (Fig. 2) does not require significant institutional resources, greater effort would likely be required to identify and correct recurrent communication failures among staff and the various service lines. However, this effort is warranted: data analyzed by The Joint Commission showed that communication failures among teams were the root causes of morbidity and mortality in more than 70% of neonatal sentinel events.[75] While specific objective metrics of team performance during obstetric maternal arrest drills need further validation,[12,90–92] we strongly support recommendations by the Joint Commission, the Confidential Enquiries into Maternal and Child Health of the United Kingdom and others emphasizing the provision of periodic emergency drills that involve both the obstetric and neonatal teams.[75,90,93–95]

Table 3. Checklist of Perimortem Cesarean Delivery Equipment for Providers' Protection, for the Procedure, and for the Neonate (In Addition to a Standard Crash Cart with Backboard)

For providers:	Surgical gloves, size 6, 7, and 8
	Gowns (for obstetricians and neonatal team)
	Masks with eye protection
For procedure*:	Sterile scalpels (one for incision, one for umbilical cord, one backup)
	Skin preparation solution (if time permits)
	Laparotomy sponges (if ROSC after delivery, pack abdomen; move to OR)
	Sharps container
	Kelly clamps × 4
	Mayo scissors
	Retractor
For neonate*:	Cord clamps
	Blankets and heated incubator
	Resuscitation supplies (bag mask, bulb suction, medication, etc.)

Maps of fastest routes to operating room should be posted where appropriate.
ROSC = return of spontaneous circulation; OR = operating room.
*Most important item is a scalpel. Perimortem cesarean delivery must not be delayed while waiting for a cesarean equipment tray.

X. QUESTIONS AND CONTROVERSIES

1. Q. The 2010 AHA guidelines now recommend C-A-B (compressions, airway, breathing) rather than A-B-C. Is C-A-B applicable to pregnant patients or should A-B-C be used?

1. A. This Consensus Statement supports the current C-A-B sequence advocated by the AHA.[15] The initial focus on the airway that was previously advocated may have detracted from the immediate provision of chest compressions. While respiratory arrest may be the initial event precipitating maternal collapse (e.g., magnesium or opioid overdose, high neuraxial block, hypoventilation after eclamptic seizure, failed intubation/ventilation after induction of general anesthesia for cesarean delivery), cardiac arrhythmias may develop concurrently or shortly thereafter. The prompt provision of high quality chest compressions with minimal interruptions is emphasized by the C-A-B sequence. Health care teams should be aware that pregnant women develop hypoxia and acidosis rapidly during apnea because of greater basal metabolic rate, decreased functional residual capacity, and fetal oxygen requirements. Adequate ventilation must therefore be initiated as soon as possible, in parallel with effective chest compressions and defibrillation, if indicated.

2. Q. Why is manual LUD recommended rather than pelvic or patient tilt?

2. A. Although a recent mannequin study demonstrated that chest compressions can be performed well in both the supine and tilted position, the study used a one-meter long, 30-degree wooden wedge[96] that likely would not be immediately available in many labor units. Tilt creates mechanical disadvantages for chest compression because transmission forces are no longer perpendicular to the thorax.[32] Tilt may also potentially complicate airway control. A study in healthy pregnant women undergoing cesarean delivery found that leftward manual uterine displacement decreased

the incidence of spinal hypotension when compared to use of a 15-degree left table tilt.[30] On balance, effective LUD in the setting of maternal arrest is probably best achieved with manual displacement.

3. Q. The ORs at an institution are located directly adjacent to the Emergency Medicine Department and the Labor and Delivery Unit. Would it not be best in this circumstance to immediately transport an arrested patient from these locations to the OR for optimal surgical conditions?

3. A. While transport to the nearby OR seems logical, simulation studies on maternal cardiac arrest and PMCD have demonstrated that, even under ideal circumstances, transport from a labor room to the OR delayed uterine incision.[70] Median (interquartile range) times from simulated maternal arrest to "incision" were approximately 4 (4–5) and 8 (7–9) minutes, respectively, when cesarean delivery was performed in the labor room compared with the OR.[70] Most of the additional time was spent on tasks associated with the preparation for and recovery from exiting the labor room and entering the OR, rather than actual transit time (50 ± 13 seconds).[70] Transport also resulted in more interruptions in chest compressions and degradation in the quality of chest compressions.[70,73] We recommend that PMCD be performed at the bedside whenever possible in any pregnant patient >20 weeks' gestation who sustains a cardiac arrest.

4. Q. A patient in labor was found in cardiac arrest 7 minutes after the last recording of a low arterial blood pressure. A nurse immediately started chest compressions upon discovering the patient. The code team arrived shortly thereafter. When should the baby be delivered in this circumstance?

4. A. The AHA recommends the immediate provision of high-quality chest compressions as well as fetal delivery within 5 minutes in the event of maternal cardiac arrest (at >20 weeks' gestation).[1] However, the following two statements both appear in the 2010 AHA Guidelines: (1)"Emergency cesarean section may be considered at 4 minutes *after onset of cardiac arrest* if there is no ROSC," and (2) "if no ROSC by 4 minutes *of resuscitative efforts*, consider performing immediate emergency cesarean section: Aim for delivery within 5 minutes of onset of resuscitative efforts" (AHA algorithm for Maternal Cardiac Arrest).[1] These two statements may create confusion with respect to situations in which resuscitative efforts do not start until several minutes after the arrest (likely a common occurrence). In the above scenario, chest compressions and BLS/ACLS should be continued while preparations are made for an immediate cesarean delivery in the labor room, but it is not necessary to wait for an additional 4 minutes to elapse before delivery. If there is no ROSC, PMCD should be performed as soon as possible to help maternal and fetal survival. The AHA also states that: "The rescue team is not required to wait 5 minutes before initiating emergency hysterotomy, and there are circumstances that support an earlier start."[1]

5. Q. Why are AEDs recommended over more sophisticated manual defibrillators?

5. A. An AED is often the best choice for initial resuscitation on the labor and postpartum unit because health care teams rendering care in those areas may be less familiar with the use of a manual defibrillator. The AHA addressed the use of AEDs in the 2010 guidelines: "Despite limited evidence, AEDs may be considered for the hospital setting as a way to facilitate early defibrillation (a goal of shock delivery <3 minutes from collapse), especially in areas where staff have no rhythm recognition skills or defibrillators are used infrequently."[15] When in AED mode, teams have access to (and the benefit of) timed two-minute intervals to guide routine analysis and shock that may be missed in the manual defibrillation (non-AED) mode unless an experienced provider is leading the resuscitation. Use of a defibrillator with both AED and non-AED modes (with default set in the AED mode) provides the Code Team with the option to use manual override upon their arrival.

6. Q. Should family members stay in the room during maternal CPR?

6. A. Some health care professionals favor escorting family members out of the room during CPR, based on concerns ranging from medico-legal liability to that of family members becoming traumatized, distressed, or disrupting/delaying critical, life-saving interventions.[97] A simulation study of emergency medicine residents demonstrated delayed defibrillation by residents randomized to scenarios including an overtly grieving family member, versus those scenarios with a quiet family member or no family member present.[98] Resuscitation in the obstetric setting may be unique because arrest or death is usually unanticipated, a happy outcome for mother and baby is the expected norm, and family are frequently present in the room at the time of collapse. In many critical obstetric events, family members would be confronted with a dire emergency in which two lives were at stake when, moments before, all was well. Witnessing an emergent PMCD during CPR of a pregnant patient may be particularly traumatic. Also, the need for multiple teams may make space a critical issue, particularly if delivery is occurring in a labor room or the Emergency Department.

Conversely, the AHA, the Emergency Nurses Association and public opinion all favor allowing family members to remain close to the patient during CPR.[97] Many family members view it as a right rather than a privilege to be with a loved one during their last moments.[97] Allowing the family to be present may facilitate the grieving process by avoiding issues of denial. One study found that relatives who did not witness CPR experienced symptoms of post-traumatic stress disorder, anxiety and depression more frequently than those who did witness CPR.[99] Loved ones may achieve closure by seeing that everything that could have been done was done. Succinctly stated, what families see during a code, although difficult, may be far less difficult than what they can imagine.[97] If the decision is made to allow family members to be present during resuscitation, a staff member not actively participating in the code should be designated to care for and support the family members.

7. Q. Is it important to remove fetal monitors before delivery of shock?

7. A. Fetal monitors are electrical contact points to both mother and fetus. If fetal monitors are present during maternal defibrillation, there is the potential for arcing or electrical burns. However, the risk is theoretic and defibrillation

should never be delayed or withheld in order to first remove fetal monitors. There are two types of monitors typically used to monitor the fetal heart rate: external and internal. If an internal fetal monitor, i.e., FSE, is being used, we recommend disconnecting the scalp monitor from the electrical source if there is a staff person present and capable of doing so. However, removal of an FSE may require additional time and/or distract from more important interventions. If an external fetal monitor is in place, removing it from the patient's abdomen should require very little time and may be necessary in preparation for PMCD. On balance, removal of either external or internal fetal monitors is recommended if the situation permits but should never delay defibrillation.

Moreover, in the setting of maternal cardiac arrest fetal monitoring is neither practical, logical or associated with any direct clinical benefit to mother or fetus. A focus on fetal monitoring during a maternal code is likely to result in the misallocation of provider attention and delays in critical interventions. If ROSC does not occur after the first few minutes of resuscitation, current recommendations are for rapid delivery for maternal and fetal benefit, regardless of fetal heart rate.[1,47–50]

8. Q. The Association of Women's Health, Obstetric and Neonatal Nurses (AWHONN) does not currently endorse an ACLS training requirement for all labor and delivery unit nurses. Should our institution require ACLS training for our labor and delivery unit nurses?

8. A. The AWHONN position statement declares that the need for ACLS training depends on the acuity of the patient population served and the availability of a code team within the facility.[100] While almost all facilities have a code team, the team's arrival on the labor and delivery unit may be delayed. Institutions should therefore conduct drills to determine the amount of time required for the code team to arrive, and should ensure that bedside personnel are prepared to manage a maternal resuscitation for at least the amount of time required for code team arrival under optimal circumstances.[90,100] While ACLS course completion may be one strategy to prepare teams, several studies have suggested that obstetric health care team members possess a poor understanding of resuscitation of the pregnant patient despite ACLS certification.[8,9,12] Furthermore, knowledge degradation may occur rapidly even for individuals who are certified in advanced life support.[7,11] Obstetric-specific resuscitation training (e.g., "OBLS") offered in conjunction with standard ACLS courses and routine obstetric emergency drills may be the most appropriate approach for obstetrical staff.[94] A subset of nurses who receive special training to perform high-risk or critical care obstetrics should be encouraged to pursue ACLS course completion.

9. Q. Why is the recommendation to place the hands higher than normal on the sternum during the provision of chest compressions to patients in their third trimester?[1]

9. A. The gravid uterus may displace the contents of the thorax, resulting in a cephalad anatomic shift in pregnant patients who are near term. Thus, for closed chest compressions to be most effective, expert opinion suggests that the hands should be placed at the sternal level under which the heart is likely to be located.[1]

10. Q. If one suspects local anesthetic-induced cardiac arrest (local anesthetic systemic toxicity [LAST]) in a pregnant patient, should lipid emulsion be administered, as in a nonpregnant patient?

10. A. Local anesthetic-induced cardiac arrest in a pregnant patient should be managed as in any other patient. The pregnant state may confer enhanced sensitivity to LAST, and cardiac toxicity resulting from high local anesthetic plasma concentrations may be particularly resistant to conventional resuscitative interventions. If standard resuscitative measures do not result in rapid ROSC, lipid emulsion should be administered as an adjunctive therapy if local anesthetic-induced cardiac arrest is suspected. The dosing and timing of lipid emulsion therapy during resuscitation of pregnant patients should follow standard algorithms used in nonpregnant patients (see below).[33,41–43,101] The fetal risk of lipid emulsion therapy remains unknown, but as in any maternal cardiopulmonary arrest, the fetus is best served by optimal management of the mother. Lipid emulsion is routinely administered as part of parenteral nutrition in severe cases of hyperemesis gravidarum and in extremely low birth-weight infants; the primary complication with the use of lipid emulsion in these settings appears to be infection.[102,103]

Lipid Emulsion Dosing Guidelines[33,41–43,101]

The initial bolus for 20% lipid emulsion for LAST is 1.5 mL/kg ideal body weight (100 mL for a 70 kg individual). The maintenance infusion is 0.25 mL/kg ideal body weight per minute, and it should be continued for at least 10 minutes after a perfusing rhythm is attained. If circulatory stability is not attained, consider re-bolusing at 1.5 mL/kg ideal body weight as before, and consider increasing maintenance infusion to 0.5 mL/kg ideal body weight per minute. The upper limit for initial dosing is approximately 10 mL/kg lipid emulsion for 30 minutes. [Propofol has cardiovascular-depressant effects and is not a substitute for lipid emulsion. In the setting of LAST refractory to standard resuscitative measures in conjunction with lipid emulsion and vasopressor therapy, the use of cardiopulmonary bypass or extracorporeal membrane oxygenation may be considered as a temporizing measure].[42,81]

11. Q. Is it necessary to use a backboard under the patient during the provision of chest compressions?

11. A. Simulation studies suggest that a backboard decreases bed mattress movement during chest compressions and, as a result, a backboard may optimize chest wall excursion. If a backboard is not available at the site of arrest, compressions can be started immediately while a designee is assigned to obtain one.[28,29]

12. Q. The use of checklists to improve team performance during a maternal cardiac arrest is recommended in this consensus statement. Why?

12. A. Checklists are an integral part of the culture of safety in other highly dynamic, high-stakes domains. In the aviation industry, checklists are used for both routine (e.g., pre-flight safety checklist), and emergent situations

characterized by extreme time pressure. For example, U.S. Airways 1549 suffered dual engine failure while mid-air. With only minutes before impact, the captain instructed the first officer to read through the checklist on emergency landings while he remained at the controls. The two successfully landed the aircraft with no casualties.[104] Checklists are slowly becoming more integrated into the medical domain for routine situations (e.g., preprocedure or preincision surgical time-outs). Simulation studies suggest checklists may help medical teams perform optimally during emergencies; however, periodic training is necessary in order to familiarize health care provider teams with their use.[77–79,105–107]

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