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Critical Care in Pregnancy

Critical care in pregnancy relies predominantly on recommendations from nonpregnant adult critical care with only limited research available for obstetric critical care specifically. The purpose of this document is to review available evidence, propose strategies for obstetric-related critical care, and highlight the need for additional research. Much of the review will, of necessity, focus on general principles of critical care, extrapolating when possible to critical care in pregnancy and the puerperium. This Practice Bulletin is updated to include information about unique issues to pregnancy when conditions such as sepsis or acute respiratory distress syndrome (ARDS) are encountered and the obstetrician's role in the management of the critically ill pregnant woman, which is dependent upon the care setting and the intensive care unit (ICU) model used. The role of the tele-intensive care unit in the care of critically ill pregnant women also is explored.

Background

The leading causes of ICU admission during pregnancy or the postpartum period are hypertensive disorders and obstetric hemorrhage (1, 2). Additional diagnoses that result in ICU admission include sepsis, trauma, respiratory conditions, cardiovascular disorders, diabetic ketoacidosis, gastrointestinal disorders (pancreatitis, appendicitis, bowel obstruction), overdose or poisoning, and neurologic disorders (2).

In the United States and similar nations, approximately 1–10 obstetric patients per 1,000 deliveries are admitted to the ICU (1). Most of these (63–92%) are postpartum admissions (1–4). Most pregnant and postpartum patients in the ICU do not require major lifesaving interventions but rather more intensive monitoring than can be provided on antepartum or postpartum units (3–5). In a recent audit of obstetric patients admitted to the ICU in the United Kingdom, median length of stay was 2.0 days for women admitted antepartum and 1.1 day for those admitted postpartum (2). The maternal death rate after ICU admission differs significantly between high- and low-income countries (median 3.3% versus 14.0%, respectively, $P=.002$) (1).

When obstetric patients are transferred to the ICU, the obstetrician–gynecologist's role will depend on the patient's status (antepartum or postpartum) and the ICU model (open or closed). Regardless, patient care decisions must be made collaboratively between the critical care specialist, obstetrician–gynecologist, neonatologist, and others on the multidisciplinary care team. Decisions also should involve the patient, her family, or both. The underpinning principles are that the woman's interests are paramount, and optimal fetal status is generally predicated on optimizing the maternal condition as much as possible. Medical interventions and diagnostic imaging may be modified to an extent but when indicated for maternal health should not be withheld purely for fetal concerns.

Although ICU admission can be used to identify cases for local review, the demand for ICU admission is often driven by factors other than medical need, such as bed availability, staffing, or local practice (3, 5). Further, using only ICU admissions as a marker for critical care needs fails to capture patients who receive some type of critical care service outside of the ICU. Therefore, ICU admission alone is not adequate as a quality or an epidemiologic marker of maternal morbidity (6). However, it may be useful for local surveillance and quality

assurance activities. It is important not to discourage ICU admission; rather, health care providers should be encouraged to use critical care services when appropriate.

Knowledge Base

The critical care physician workforce has traditionally been drawn from surgery, anesthesiology, internal medicine and, more recently, emergency medicine. After residency training, physicians complete a 1–3-year fellowship in critical care medicine. Critical care fellowships accept obstetrics and gynecology residency graduates who ultimately become eligible to sit for critical care boards. Some maternal–fetal medicine programs also offer a combined fellowship. Without committing to an extensive formal training program, interested obstetrician–gynecologists can expand their knowledge of critical care through the Society for Maternal–Fetal Medicine or Society of Critical Care Medicine courses, which combine didactic and simulation sessions. (See www.acog.org/More-Info/CriticalCareinPregnancy, or the For More Information section for resources.)

Admission to Intensive Care

Intensive care unit beds are a scarce resource with an eightfold difference among high-income countries ranging from three ICU beds per 100,000 population in the United Kingdom to 25 ICU beds per 100,000 in Germany, with the United States having approximately 20 ICU beds per 100,000 population. (7). Generally, in the United States, ICUs are distinguished by a nurse-to-patient ratio of 1:2 or less and the presence of specialized equipment whether for monitoring or for organ support. But not all patients who might benefit from high-acuity nursing or equipment will be admitted to an ICU. Admission to the ICU should take into account objective clinical parameters that reflect instability, the potential for the patient to benefit from high acuity interventions, underlying diagnoses and prognoses, availability of clinical expertise in the current setting, and ICU beds.

Facility-level factors may influence the decision to transfer a patient to a higher level of care. These factors include lack of adequate staff to care for a critically ill patient, need for frequent assessments, special equipment, or administration of medications that require close monitoring. When a request is made to transfer a patient to a higher level of care for facility-level factors, a discussion between the transferring health care provider and the intensive care providers regarding the current limitations of care on the obstetric unit may help facilitate rapid transfer, which is ultimately in the patient's best interest.

A guideline for rational allocation of critical care beds was put forward by the Society for Critical Care Medicine (8). For this allocation system, patients are prioritized based on severity of illness and likelihood of recovery with ICU therapies (8).

Not all women who require a higher level of care will need admission to an ICU. Some patients can be successfully monitored in an intermediate care unit, also known as a stepdown or high-dependency unit. A high-dependency unit may be a stand-alone unit, although on busy obstetric units, there often will be a version of a high-dependency unit on the labor and delivery floor. They are sometimes referred to as Obstetric Intermediate Care Units, but they are not equipped as full-service ICUs. They may handle invasive monitoring (arterial or central lines or, although rarely now, pulmonary artery catheters) but typically do not handle mechanical ventilation (9).

In caring for a woman with deteriorating clinical status, the adoption of set parameters for bedside evaluation by a health care provider may be of benefit in making the decision to transfer the woman to the ICU or other unit that can provide a higher level of care. The National Partnership for Maternal Safety proposed vital sign parameters that were intended to trigger a bedside evaluation by the treating physician with care escalation as needed (Box 1). For pregnant women with suspected infection who are being evaluated in the emergency department, there is also an existing scoring system that predicts the need for ICU admission. This scoring system, the Sepsis in Obstetrics Score, may have utility in identifying women with more severe illness (10, 11). This scoring system has been validated only at a single institution (11), so further assessment of the performance of this scoring system in other patient populations is needed to determine its utility. Clinical judgment can always supersede scoring systems and published vital sign parameters when determining who requires ICU admission.

Box 1. Maternal Early Warning Criteria From the National Partnership for Maternal Safety

Maternal Early Warning Criteria

- Systolic BP (mm Hg) <90 or >160
- Diastolic BP (mm Hg) >100
- Heart rate (beats per min) <50 or >120
- Respiratory rate (breaths per min) <10 or >30
- Oxygen saturation on room air, at sea level, % <95
- Oliguria, mL/hr for ≥ 2 hrs <35
- Maternal agitation, confusion, or unresponsiveness;
- Patient with preeclampsia reporting a non-remitting headache or shortness of breath

Abbreviation: BP, blood pressure

Reprinted from Mhyre JM, D'Oria R, Hameed AB, Lappen JR, Holley SL, Hunter SK, et al. The maternal early warning criteria: a proposal from the national partnership for maternal safety. *Obstet Gynecol* 2014;124:782–6.

Patients that require mechanical ventilation or hemodynamic support or who have complex, life-threatening conditions or organ failure, require critical care in a full-service ICU. The Society for Critical Care Medicine published guidelines for ICU admission, discharge, and triage to serve as a framework for clinical care (8). The underlying principle of these recommendations is that individual institutions and their ICU leaders should develop policies to meet their population's needs with consideration of available resources.

Considerations in Transfer

If a pregnancy is complicated by a critical illness or condition, the woman should be cared for at a hospital with obstetric services, an adult ICU, advanced neonatal care services, and appropriate hospital services such as a blood bank. Of the nearly 5,500 acute-care hospitals in the United States (12), approximately one half offer obstetric services and approximately 1,500 have neonatal intensive care units (13).

For cases in which a higher level maternal care facility is required for critically ill women, consideration should be given to transport as soon as the need is identified and the patient is stable for transport (14). In some cases, the receiving facility may need to help the referring team stabilize the patient for transport using the available resources. Transfer back to lower levels of care may be appropriate after the original condition has resolved.

Common Causes of Maternal Intensive Care Unit Admission

Massive obstetric hemorrhage and hypertensive disorders of pregnancy are common causes of ICU admission in pregnancy or immediately postpartum. Typically, admissions for these conditions are necessary for invasive monitoring or massive transfusion protocols in the setting of hemorrhage, or for intravenous antihypertensive medications in women with preeclampsia and refractory severe hypertension. Management of hypertensive disorders and obstetric hemorrhage are detailed in other American College of Obstetricians and Gynecologists' documents (15–17). (See the For More Information section). Given the high prevalence of sepsis and the complication of ARDS in pregnancy, these topics are reviewed briefly here.

Sepsis

Sepsis is currently understood as a “life-threatening organ dysfunction caused by a dysregulated host response to infection” (18) and remains a leading cause of maternal mortality (19). In the Third International

Consensus Definitions for Sepsis and Septic Shock (Sepsis-3) from the Society of Critical Care Medicine and the Society of European Intensive Care Medicine, the terms systemic inflammatory response syndrome and severe sepsis were abandoned in favor of simply using the categories of infection, sepsis, and septic shock. In the consensus statement, patients without organ dysfunction are classified as having an infection. Sepsis is defined as infection with organ dysfunction, and septic shock is a subset of sepsis in which patients require vasopressor support to maintain a mean arterial pressure greater than 65-mm Hg and have a serum lactate level greater than 2 mmol/L after adequate fluid resuscitation. These changes in terminology should not delay treatment for pregnant women who have infections because they still require prompt attention, broad-spectrum antibiotic therapy, and fluid resuscitation.

A screening test, the Quick Sequential Organ Failure Assessment, was also proposed as part of the consensus statement to help stratify risk in patients with infection. For Quick Sequential Organ Failure Assessment, any two of the following are considered a positive screen and indicate a need for further assessment: systolic blood pressure (BP) 100-mm Hg or less; respiratory rate 22 breaths per minute or more; or an altered mental status. These parameters have not been adjusted for pregnancy physiology and, at this time, there are no studies on sepsis in obstetrics that make use of the Quick Sequential Organ Failure Assessment score or the new sepsis definitions. In nonpregnant adults, when the Quick Sequential Organ Failure Assessment score is 2 or 3, health care providers should search for signs of organ dysfunction with clinical and laboratory evaluation and consider infection as a possible cause (20). The clinician should be aware that fever may be absent, cultures may be negative, and a source is not always identifiable (21, 22). Sepsis remains a clinical condition without a diagnostic test.

Treatment for sepsis is predicated on timely suspicion, fluid resuscitation, and antibiotic therapy within the first hour (23). Early antibiotic therapy for sepsis is recommended to reduce mortality. Each hour of delay is associated with an increase in mortality for patients with sepsis or septic shock (23). Guidelines for management (not specific to obstetrics) can be found at www.survivingsepsis.org (see the For More Information section). Although an initial randomized trial demonstrated mortality benefit of early goal-directed therapy for sepsis (24), more recent trials have not (25–27). The rate of survival was higher in more recent trials than in the initial trial, which may demonstrate other improvements in the care of patients with sepsis and septic shock.

Acute Respiratory Distress Syndrome

Acute respiratory distress syndrome is a nonspecific response of the lung to a variety of insults, characterized by diffuse inflammation, increased fluid level in the lung due to increased vascular permeability, and loss of aerated lung units (28). Pregnant women are at increased risk of developing ARDS and needing mechanical ventilation compared with nonpregnant women (29–31). In practice, ARDS is seen most commonly in the setting of sepsis with infections such as influenza and pyelonephritis. Acute respiratory distress syndrome also can be seen as a complication of obstetric diagnoses such as preeclampsia or amniotic fluid embolism. Clinical vigilance is warranted for pregnant women with pulmonary symptoms because they can rapidly progress to respiratory failure.

The understanding of the epidemiology of ARDS in pregnancy is somewhat in flux, perhaps because of differences in definitions and study design. Between 2008 and 2009, there were three cases of ARDS during postpartum hospitalizations per 10,000 delivery hospitalizations (32). Mortality among obstetric patients with ARDS had been reported as 22–44% in older case series (29, 33, 34), but these rates do not reflect contemporary understanding or management of ARDS. In Canada, mortality from ARDS in an obstetric population was approximately 3% between 2003 and 2007 (35). When investigating severe maternal morbidity and mortality in the United States, one study (2012) identified a diagnosis of respiratory distress syndrome in 33% of maternal deaths from 1998 to 2009 (32).

Acute respiratory distress syndrome was redefined in 2012 based on a combination of clinical and radiographic findings (28). In order to meet criteria for ARDS, the onset of respiratory failure must be within 1 week of a known clinical event with evidence of bilateral opacities on chest imaging, and no other identifiable etiology such as cardiac failure or fluid overload. As defined by the ARDS Definition Task Force, the degree of ARDS severity (mild, moderate, severe) is based on oxygenation as measured by the partial pressure of arterial oxygen to fraction of inspired oxygen ($\text{PaO}_2/\text{FIO}_2$) ratio (28).

With ARDS, the lungs are poorly compliant, which greatly increases the patient's work of breathing, and hypoxemia is often profound. The most salient change in management of ARDS has been the move toward low-tidal-volume ventilation. Although mechanical ventilation is life-saving, both high concentrations of oxygen and the physical effects of positive pressure ventilation can damage the lungs. Low-tidal-volume ventilation, which aims to limit inflation pressures rather than trying to normalize arterial blood gases, has been shown in

a randomized controlled trial to significantly decrease mortality in a nonpregnant adult population (36). No studies have evaluated the efficacy of this strategy in pregnant and postpartum women.

Clinical Considerations and Recommendations

► *What factors contribute to the decision to move a pregnant patient to the intensive care unit?*

In general, a higher level of care should be sought when a patient is clinically unstable (eg, hypotensive or hypoxemic), at high risk of deterioration (eg, increasing work of breathing), or overtly needs specialized ICU care such as mechanical ventilation. Laboratory work, such as obtaining an arterial blood gas and serum lactate measurement, also may be useful to identify women with progressive clinical deterioration for whom ICU admission can be considered (37). An obstetrics scoring system based on vital signs and laboratory parameters exists to predict the likelihood of ICU admission for women who have an infection (10). However, it is unknown whether this scoring system decreases the time to admission to the ICU or improves outcomes. In addition, this scoring system was developed and validated (11) in a single tertiary center and may not be as useful in other centers because the need for transfer to the ICU depends largely on available resources and staff capabilities in the labor and delivery and postpartum units.

The Quick Sequential Organ Failure Assessment can also be used to stratify risk in patients who have infections. However, the parameters of this screening test have not been adjusted for pregnancy physiology. In nonpregnant adults, when the Quick Sequential Organ Failure Assessment score is 2 or 3, health care providers should search for signs of organ dysfunction with clinical and laboratory evaluation and consider infection as a possible cause (20).

Most obstetric admissions to the ICU occur postpartum, heavily weighted by hypertension and major obstetric hemorrhage (1, 2). Most of these patients require level 2 care (monitoring and simple interventions) rather than level 3 care (major organ support). Thresholds for ICU admission appear to vary by facility, notably by facility size: hospitals with lower delivery volumes make more use of their ICUs for obstetric patients compared with hospitals with busier obstetric services (38). This probably does not reflect a sicker obstetric population in smaller hospitals, but a preference for ICU transfer at lower levels of acuity.

► ***What is the obstetrician–gynecologist’s role in the transfer of a patient to a critical care unit and the patient’s management there?***

Transfer Between Hospitals

The care of any pregnant woman who requires ICU services ideally should be managed in a facility with obstetrics, adult ICU, and neonatal ICU capability. Maternal transport facilitates access to a higher level of care for the woman and the neonate. Guidelines for perinatal transfer, including maternal transport, have been published by the American College of Obstetricians and Gynecologists and the American Academy of Pediatrics (39). Pretransport evaluation of the woman and her fetus must be performed, and maternal status must be stabilized before transport. In most cases, maternal stabilization for transport can be achieved with assistance from the accepting facility. However, in situations when maternal transport is unsafe or impossible, or when imminent delivery is anticipated, arrangements can be made for postpartum rather than antepartum maternal transport.

Necessary transport monitoring for a critically ill pregnant woman (or for a woman during the postpartum period) includes continuous cardiac rhythm and pulse oximetry monitoring, and regular assessment of vital signs. Venous access must be established before transport, and all existing lines should be secured. Left uterine displacement should be routine during transport. If there is a high probability that intubation and mechanical ventilation will be needed during transport, it should be accomplished before departure (40). Fetal monitoring and tocodynamometry during the transport process may be feasible but its utility is unknown, and interventions are seldom feasible en route due to space restrictions. Therefore, the use of fetal monitoring during transport should be individualized (39). Transport should not be delayed by the inability to provide fetal monitoring in a critically ill pregnant woman. Optimization of maternal status will optimize fetal status. When fetal monitoring is possible, heart rate decelerations may signal the need for maternal resuscitative measures or alert the receiving team of the need to prepare for delivery soon after arrival. Delivery during air medical transport is quite uncommon, even when preterm labor is the reason for interhospital transfer (41). Stability should be assessed before transport in conjunction with the receiving physician.

Transport crews are variable in composition but may include emergency medical technicians, paramedics, respiratory therapists, or nurses. It is uncommon for physicians or advanced practice providers (eg, nurse practitioners and physician assistants) to play a role in the

physical transport of patients in the United States (42). However, obstetrician–gynecologists at the referring or receiving hospital may be called upon to help assess whether a critically ill pregnant patient is stable for transfer, give an opinion about medical interventions before arrival, or prepare for interventions at the receiving hospital.

Transfer Within the Hospital

If a pregnant patient or a patient who has given birth is to be transferred from the obstetric department to an ICU within the same hospital, communication between the obstetrician–gynecologist and critical care services is crucial. In some cases (eg, planned cesarean hysterectomy for placenta accreta), it will be possible to request an ICU bed in advance, but forethought is not possible in all cases. Given the constraints on ICU beds and staffing, it is prudent to involve critical care staff early in the process when ICU transfer is contemplated. After the patient is accepted for ICU transfer, the physical process requires appropriate personnel and equipment to accompany her. During transport, the team must be able to assess BP, heart rate, and oxygenation status. For transporting a critically ill patient within the hospital, the team also should have a cardiac monitor with defibrillator, airway management equipment, oxygen, and basic resuscitation medications. At least two health care professionals should accompany the patient during transport to respond to emergencies or instability during the process. Similar considerations guide the transport of a critically ill obstetric patient out of the ICU for transfer to diagnostic imaging, the operating room, or back to the labor and delivery unit. Decisions on fetal monitoring during transport should be individualized based on gestational age, maternal hemodynamic status, and feasibility of intervention in response to abnormalities in the fetal heart rate tracing.

Role of the Obstetrician–Gynecologist When an Obstetric Patient Is in the Intensive Care Unit

Knowing the ICU model and type will help to define the obstetrician’s role in patient care, which may be as the primary physician or as a consultant to the intensivist team. In an open model, the patient remains the responsibility of her primary or referring team. In a closed model, the patient is transferred to the ICU team, which takes over sole responsibility for managing the patient including writing orders. A hybrid, transitional, or semi-open model is one in which the primary team still admits to the ICU, but an automatic critical care consult is incurred (43). Intensive care units can be medical,

surgical, combined medical–surgical, or specialty (eg, cardiothoracic, neurologic). In tertiary care centers, it is common to have several options for critical care beds; obstetric patients may be preferentially admitted to one or another, depending on local patterns and on the condition that requires ICU transfer.

Regardless of the type of ICU, obstetricians can provide expertise when weighing the risks and benefits of interventions such as medication administration and diagnostic imaging. Additionally, obstetrician–gynecologists can work with the intensive care team to interpret vital signs and laboratory parameters affected by pregnancy (Table 1) and make recommendations regarding fetal monitoring and delivery planning when indicated. Daily rounds, frequent communication with the ICU team, and a rapid response to calls for consultation are all important. When obstetric patients are transferred to the ICU, patient care decisions including mode, location, and timing of delivery ideally should be made collaboratively between the intensivist, obstetrician–gynecologist, and neonatologist, and should involve the patient and her family when possible.

Multidisciplinary care plans should be developed, with attention to maternal and, when relevant, fetal status. Decisions must be made about fetal monitoring based on the gestational age of the fetus, desires of the patient and her family, and feasibility of intervention based on maternal status. Ideally, planning for delivery includes a discussion of the preferred mode and the location of delivery, the need for analgesia or anesthesia, and the availability of pediatricians for neonatal resuscitation. Because the risk–benefit considerations for continued pregnancy versus delivery are likely to change as the pregnancy and critical illness progress, the care plan must be reevaluated regularly. In situations when there is an acute deterioration in the patient’s clinical condition, immediate reassessment of continuing the pregnancy versus delivery should be undertaken.

Input from obstetrician–gynecologists in the care of postpartum ICU patients may include evaluation of vaginal or surgical site bleeding, obstetric sources of infection, therapies (such as magnesium for eclampsia prophylaxis), and expertise in lactation. There may be surgical issues, such as re-exploration of the abdomen or reclosure of abdominal and perineal or vaginal incisions. The obstetrician–gynecologist, in conjunction with personnel in neonatology, should also advocate for bringing together the critically ill woman and her neonate when possible.

► ***Are there special considerations in the care of a pregnant woman in a critical care setting?***

Maternal stabilization is the first priority when caring for critically ill pregnant women. If the woman is stable, it is important to determine the fetal gestational age because

this is likely to affect the plan of care. When possible, prenatal care records should be obtained and reviewed to ascertain the best available dating. In the event that gestational age remains uncertain, bedside ultrasound evaluation can establish an estimated gestational age for immediate decision-making.

Pregnancy often modifies drug effects or serum levels. Drugs that cross the placenta may have fetal effects; for example, sedative and parasympatholytic drugs alter fetal heart rate tracing. Medications commonly used in critical care settings may have adverse effects on the pregnancy such as decreased placental perfusion or increased risk of malformations. In addition, many common obstetric medications may pose particular challenges for the woman. Examples of common drug-related adverse effects include tachycardia and decreased BP with beta-agonists, and negative inotropic effects on cardiac function with magnesium. Known adverse effects on the woman and the fetus must be carefully monitored, potential drug interactions considered, and risk–benefit ratios assessed in each individual situation. Neither necessary medications nor diagnostic imaging should be withheld from a pregnant woman because of fetal concerns, although attempts should be made to limit fetal exposure to ionizing radiation (44) and teratogenic medications when feasible.

Administration of steroids for fetal benefit should be considered in women admitted to the ICU in the preterm period. A single course of betamethasone or dexamethasone is recommended for pregnant women between 24 0/7 weeks of gestation and 33 6/7 weeks of gestation at risk of preterm birth within 1 week in order to reduce neonatal mortality and some complications of prematurity (45). There may be some neonatal benefit as early as 23 weeks of gestation and steroids can be offered at 23 0/7 weeks of gestation depending on the family’s decision regarding neonatal resuscitation (46).

Based on the Maternal–Fetal Medicine Units Network Antenatal Late Preterm Steroids trial (47), steroids administered between 34 0/7 weeks of gestation and 36 6/7 weeks of gestation reduce the risk of neonatal respiratory morbidity. However, antenatal corticosteroids have not been tested in the setting of critical maternal illness, and steroids may cause hyperglycemia, hypokalemia, leukocytosis, and impaired wound healing. Thus, the risks and benefits of steroid administration (especially in the late preterm period) should be weighed with special attention to the perceived likelihood of delivery in the next 7 days. Indicated delivery should not be delayed for administration of steroids in the late preterm period (45).

Fetal monitoring is often used for critically ill pregnant women. Decisions regarding fetal monitoring should be made proactively and will depend on the specific clinical

Table 1. Physiologic Changes of Pregnancy That Affect Resuscitation

Cardiovascular		Effect
Increased	Plasma volume by 40 to 50 percent, but erythrocyte volume by only 20 percent Cardiac output by 40 percent Heart rate by 15 to 20 beats per minute Clotting factors susceptible to thromboembolism Dextrorotation of the heart Estrogen effect on myocardial receptors	Dilutional anemia results in decreased oxygen carrying capacity Increased CPR circulation demands Increased CPR circulation demands Increased EKG left axis deviation Supraventricular arrhythmias
Decreased	Supine blood pressure and venous return with aortocaval compression Arterial blood pressure by 10 to 15 mm Hg Systemic vascular resistance Colloid oncotic pressure (COP) Pulmonary capillary wedge pressure (PCWP)	Decreases cardiac output by 30 percent Susceptible to cardiovascular insult Sequesters blood during CPR Susceptible to third spacing Susceptible to pulmonary edema
Respiratory		Effect
Increased	Respiratory rate (progesterone-mediated) Oxygen consumption by 20 percent Tidal volume (progesterone-mediated) Minute ventilation Laryngeal angle Pharyngeal edema Nasal edema	Decreased buffering capacity Rapid decrease of PaO ₂ in hypoxia Decreased buffering capacity Compensated respiratory alkalosis Failed intubation Failed intubation Difficult nasal intubation
Decreased	Functional residual capacity by 25 percent Arterial PCO ₂ Serum bicarbonate	Decreases ventilatory capacity Decreases buffering capacity Compensated respiratory alkalosis
Gastrointestinal		Effect
Increased	Intestinal compartmentalization	Susceptible to penetrating injury
Decreased	Peristalsis, gastric motility Gastroesophageal sphincter tone	Aspiration of gastric contents Aspiration of gastric contents
Uteroplacental		Effect
Increased	Uteroplacental blood flow by 30 percent of cardiac output Aortocaval compression Elevation of diaphragm by 4 to 7 cm	Sequesters blood in CPR Decreases cardiac output by 30 percent Aspiration of gastric contents
Decreased	Autoregulation of blood pressure	Uterine perfusion decreases with drop in maternal blood pressure

(continued)

Table 1. Physiologic Changes of Pregnancy That Affect Resuscitation (continued)

Breast		Effect
Decreased	Chest wall compliance secondary to breast hypertrophy	Requires increased CPR compression force
Renal/Urinary		Effect
Increased	Compensated respiratory alkalosis	Decreases buffering capacity and increases acidosis during CPR
	Ureteral dilation, especially right side	Interpretation of radiographs
Decreased	Bladder emptying	Interpretation of radiographs

Abbreviations: CPR, cardiopulmonary resuscitation; EKG, electrocardiogram.

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scenario, staff availability for interpretation of the fetal heart rate tracing, and stability of the patient for intervention if indicated. In addition to prompting delivery for concerning fetal status, changes in the fetal heart rate tracing can prompt interventions to further optimize maternal status. Because electronic fetal heart rate monitoring reflects uteroplacental perfusion and fetal acid-base status, changes in baseline variability or the new onset of decelerations may reflect worsening maternal end-organ function. Therefore, even in a situation in which delivery may not be possible, fetal heart rate monitoring can be useful. Changes in fetal heart rate monitoring should prompt reassessment of maternal BP, oxygenation, ventilation, acid-base balance, or cardiac output. Correction of these factors may result in improvement of the tracing and allow for fetal and maternal resuscitation without necessitating delivery. If fetal monitoring is pursued for optimization of perfusion with the knowledge that the patient is not stable for operative delivery, a clear plan must be made with all team members and the patient's family with the understanding that delivery is not safe regardless of deterioration in the fetal heart rate tracing.

In the postpartum period, obstetricians should continue to be involved with the patient's care and may need to make recommendations related to the safety of medications while breastfeeding. Provision of lactation support and a breast pump may also be considered when feasible.

► ***How should care be organized when a laboring patient needs critical care?***

A multidisciplinary group should be convened to make decisions regarding the appropriate location for critically ill laboring patients. The convened team should consider not just the patient's physical location (obstetric unit versus the ICU), but also the specific clinical circumstances and available hospital resources. If the fetal gestational age

is before viability, managing the woman on an obstetric unit is unlikely to be the best option. However, if adequate maternal support, monitors, and medications can be provided, labor with a fetus at a gestational age beyond viability is often best managed on an obstetric unit. If the patient stays in the obstetric unit, a nurse with critical care experience should be available at the bedside to implement the pertinent components of her critical care. Alternatively, if the patient is laboring in the ICU, a qualified obstetric nurse will need to be at the bedside in the ICU to implement the obstetric components of her care.

When contemplating delivery in the ICU, advantages (eg, the availability of critical care staff and interventions) must be weighed against disadvantages (eg, lack of space to conduct a vaginal delivery and accommodate neonatal staff and equipment, and unfamiliarity of critical care personnel with obstetric management and interventions). Factors that will affect this decision include the degree of patient instability, anticipated interventions, staffing and expertise available, expected duration of ICU stay, gestational age, and probability of vaginal versus cesarean delivery.

There may be more need for instrumental assistance in vaginal delivery, either because it is advisable to avoid Valsalva maneuver in many maternal medical conditions or because women who are mechanically ventilated cannot push. Adequate analgesia is appropriate for laboring women in the ICU just as for any other laboring woman, although an assessment of pain may be complicated by altered mental status or difficulty in communication. Inadequately treated pain can result in hemodynamic changes that must be anticipated and treated. Regional analgesia is preferred but may be impossible because of coagulopathy, hemodynamic instability, or limitations to patient positioning or cooperation. Parenteral or

inhalational analgesics can be used as an alternative to neuraxial techniques (48).

Cesarean delivery in the ICU is complex and has significant disadvantages compared with the same procedure performed in a traditional operating room. These disadvantages include inadequate space for anesthetic, surgical, and neonatal equipment, as well as attendant personnel unfamiliar with the operation. In addition, ICUs have the highest rates of health care-associated infections in a hospital, so the risk of nosocomial infection with drug-resistant organisms is higher (49). Cesarean delivery in the ICU should be restricted to cases in which transport to the operating room cannot be achieved expeditiously and safely, or to a perimortem procedure. If cesarean delivery in the ICU is anticipated, obstetrician–gynecologists should ensure that necessary equipment is available including a tray with the operative instruments and a cord clamp. Pediatric personnel also should be involved in delivery planning to ensure that all necessary neonatal resuscitation equipment and a warmer are available. However, in the case of an emergent or perimortem procedure, the case can be initiated with only a scalpel while other team members gather additional equipment and resources.

► ***What critical care tools and techniques are employed in the care of pregnant and postpartum patients?***

Mechanical Ventilation

Intubation and mechanical ventilation are undertaken when hypoxemia is profound and cannot be corrected by noninvasive means, or when ventilation is failing, which means that the partial pressure of carbon dioxide in arterial blood (P_{aCO_2}) is increasing to an unacceptable level. Except in cases of central disturbance of respiratory drive, an increasing P_{aCO_2} implies that the work of breathing is too high. It is important to interpret arterial blood gases during pregnancy with an awareness of pregnancy physiology that results in a compensated respira-

tory alkalosis (50). For instance, a P_{aCO_2} of 40-mm Hg in a pregnant patient is concerning for progressive respiratory failure, although this is a normal value for a non-pregnant adult (Table 2).

Airway management in pregnancy can be challenging as a result of changes in respiratory physiology and anatomy. The increased minute ventilation and decreased functional residual capacity characteristic of pregnancy mean that hypoxemia occurs quickly after apnea. Increased airway edema and increased breast size make positioning and direct laryngeal visualization more difficult. The risk of failed intubation in obstetrics is as high as 1 in 224 attempts (95% CI, 179–281), a rate eight times higher than in the general population (51). Once the decision to intubate is made, the patient should be preoxygenated and suction should be available; the most qualified person available should intubate. A plan for failed intubation must be made ahead of time, and emergency airway management tools should be immediately available.

Ventilator settings typically are managed by the critical care team. Ventilators have different modes including controlled, assist-controlled, and intermittent mandatory. Unlike spontaneous breathing, machine inspiration is delivered through positive pressure. Breaths may be triggered by the patient or by elapsed time since the last breath. The ventilator may cycle on pressure or on volume: that is, gas may flow from the machine until a preset pressure is achieved or a preset volume is reached. The effect of different ventilator modes or settings has not been studied in pregnancy or postpartum.

Hemodynamic Monitoring

Central venous catheters may be used in the ICU to administer fluids or medications, or to monitor central venous pressure as an index of preload. It is subject to the same assumptions as the pulmonary artery occlusion pressure and instead of assuming that the left ventricular end-diastolic volume corresponds to a pressure measured in the pulmonary artery, one must assume that it

Table 2. Arterial Blood Gas Changes in Pregnancy (Sea Level)

ABG Measurement	Nonpregnant State	Pregnancy State	
		First Trimester	Third Trimester
pH	7.40	7.42–7.46	7.43
P_{aO_2} (mm Hg)	93	105–106	101–106
P_{aCO_2} (mm Hg)	37	28–29	26–30
Serum HCO_3^- (mEq/L)	23	18	17

Abbreviation: ABG, arterial blood gas

Reprinted from Hegewald MJ, Crapo RO. Respiratory physiology in pregnancy. Clin Chest Med 2011;32: 1–13.

corresponds to pressure measured in the central venous system (the catheter is not advanced into the right atrium). The relative change in central venous pressure after an intervention is more reliable than the absolute value. Risks of central venous cannulation include pneumothorax, arterial puncture, thrombosis, and catheter-related infection. Ultrasonography is commonly used to guide vascular insertion. The subclavian or internal jugular vein is preferable to femoral access in a pregnant patient (52).

Arterial cannulation is indicated when instantaneous BP monitoring is needed, as in shock or with vasoactive medications, or when frequent sampling of arterial blood gases is needed. The radial artery is most commonly accessed, but any easily accessible artery other than the carotid artery can be used. In a pregnant patient, the femoral site should be avoided. There is a risk of ischemia distal to the cannulated site; other risks are infection and thrombosis (52).

The pulmonary artery catheter (or Swan–Ganz catheter) is an invasive monitor inserted through the central venous circulation, past the right atrium and right ventricle, and floated into the pulmonary artery (52). It can be used to directly measure pressure in the right atrium and the pulmonary artery, and indirectly measure pressure further downstream (eg, the pulmonary capillary wedge pressure or pulmonary artery occlusion pressure). Known risks of the device include cardiac arrhythmias, pulmonary hemorrhage, pulmonary artery rupture or thrombosis, balloon rupture and embolization, intracardiac catheter knotting, and vascular infection (53). For many years, the pulmonary artery catheter was widely used in critical care medicine. However, its use was not associated with decreased mortality (54–59), and it has largely been replaced by minimally invasive monitoring (53).

Using minimally invasive monitoring, cardiac output can be determined by pulse contour analysis obtained from a peripheral arterial catheter. Since a relationship is known (or can be computed) between the pressure in the peripheral artery and the aorta, aortic pressure can then be calculated. Some devices then infer cardiac output from heart rate, mean arterial pressure, age, height, and weight. There are noninvasive systems that have been used in obstetrics (in cesarean delivery and management of preeclampsia) and perform well when compared with measurements of cardiac output derived from the pulmonary artery catheter (60, 61). However, given that cardiac output measurements are based on proprietary algorithms that incorporate patient biometric variables, it will be important to ensure that algorithms and specific monitoring systems continue to be validated in pregnancy.

Point-of-Care Ultrasonography

Point-of-care ultrasonography has become increasingly important in critical care medicine (62, 63). It is used to guide procedures (eg, vascular access, paracentesis, and thoracentesis); establish, confirm, or exclude diagnoses (eg, ascites, mechanical reasons for acute renal failure, and lower extremity deep venous thrombosis); and direct therapies. It can be used to predict fluid responsiveness by measuring the diameter or collapsibility of the inferior vena cava (rather than using central venous pressure), to assess left ventricular systolic and diastolic function, quickly ascertain causes of hemodynamic instability and shock so that the correct treatment can be implemented, and as an adjunct to resuscitation in conditions such as pulseless electrical activity. This technology is rapidly replacing many of the older tools of critical care medicine. It should be noted that there is limited information on using point-of-care ultrasonography in the critically ill pregnant patient; more research is needed.

► *What is the role of resuscitative hysterotomy in the setting of maternal cardiopulmonary arrest?*

Cardiac arrest in pregnancy is treated with the same ratio of chest compressions to breaths, respiratory support, drugs, and defibrillation as for any adult in cardiac arrest. It is important to achieve left uterine displacement during cardiopulmonary resuscitation in order to alleviate aortocaval compression. The American Heart Association recommends manual uterine displacement, rather than tilting the patient, because it allows for more effective chest compressions and better access for airway management and defibrillation (64).

If efforts to resuscitate a pregnant woman in cardiac arrest have been unsuccessful, resuscitative hysterotomy (eg, perimortem cesarean delivery) is recommended for maternal benefit in women with a uterine size at or above the umbilicus (20 weeks of gestation or more) (64). Resuscitative hysterotomy may help permit the return of spontaneous circulation by emptying the uterus and alleviating aortocaval compression and thereby increasing cardiac output, which may improve the efficacy of cardiopulmonary resuscitation. In addition, it may aid fetal survival despite the woman's death. In a review of 74 third-trimester cases, 45% of women died despite perimortem cesarean delivery, 45% survived without obvious sequelae, and 10% survived with significant morbidity (65). Of the involved fetuses, 23% died, 57% survived without obvious sequelae, and 19% survived with significant morbidity. Similarly, data from the United Kingdom Obstetric Surveillance System support a survival rate as high as 58% after maternal cardiac

arrest; perimortem cesarean delivery was used in most of these cases (66).

Consideration of resuscitative hysterotomy should occur as soon as there is a maternal cardiac arrest and preparations should begin in the event that return to spontaneous circulation does not occur within the first few minutes of maternal resuscitation. Once the decision is made to perform a resuscitative hysterotomy, there is no reason to move a patient to an operating room or undertake extensive preparations. The operative area can be splashed with an antiseptic if available. The only essential instrument in this setting is a scalpel.

Although the conventional teaching is that resuscitative hysterotomy should be undertaken after 4–5 minutes of arrest without return of spontaneous circulation (67, 68), obstetricians should be aware that there is no obvious threshold for death or damage at 4–5 minutes; instead there is a progressive decrease in the likelihood of injury-free survival for women and fetuses with lengthening time since cardiac arrest (65). Survival curves for women and neonates have shown 50% injury-free survival rates with perimortem cesarean delivery as late as 25 minutes after maternal cardiac arrest (65), so even if delivery does not occur within 4–5 minutes, there still may be benefit and resuscitative hysterotomy should be considered. However, more rapid resuscitative hysterotomy has been associated with improved survival (66), and the procedure should be considered as soon as initial resuscitative measures are unsuccessful.

► ***How may tele-intensive care units be used to expand access to critical care expertise and subsequently improve clinical outcomes in obstetrics?***

High-intensity ICU staffing, which mandates intensivist involvement for all patients admitted to the ICU through the closed model or through a mandatory consultation model, is associated with better mortality outcomes and is, therefore, recommended over lower-intensity approaches, such as the open unit with elective consultation (8, 69). However, the supply of intensivists has not kept up with demand, which has led to a search for solutions. Proposals have been made to augment the critical care workforce with highly trained physician assistants and nurse practitioners collaborating with physicians who often have to supervise units from a distance (70). This leads inevitably to a consideration of telemedicine, which now covers at least 11% of ICU beds for adults in the United States (71).

Tele-intensive care units allow intensivist consultation, collaboration, and supervision of care in facilities that do not have high-intensity intensivist staffing. Data are still limited regarding outcomes under this model,

and interpretation of results is confounded by varying definitions of tele-intensive care unit and by study design (72). There are data in the neuro critical care literature that support the utility of a telemedicine model for reduction of unnecessary transfers, decreased cost of care, and faster access to subspecialist interpretation of imaging (73). Similarly, in the pediatric literature, telemedicine reduced admissions to the pediatric ICU and improved health care provider-reported accuracy of patient assessment (74). Extrapolation of these findings to the obstetric population would suggest that smaller facilities may benefit from establishing a relationship for teleconsultation with a larger center with full-time intensivists and maternal–fetal medicine specialists. However, data are needed to establish the effect of telemedicine on obstetric critical care before making more specific recommendations.

Recommendations and Conclusions

The following recommendation is based on good and consistent scientific evidence (Level A):

- Early antibiotic therapy for sepsis is recommended to reduce mortality.

The following recommendations are based on limited or inconsistent scientific evidence (Level B):

- Neither necessary medications nor diagnostic imaging should be withheld from a pregnant woman because of fetal concerns, although attempts should be made to limit fetal exposure to ionizing radiation and teratogenic medications when feasible.
- If efforts to resuscitate a pregnant woman in cardiac arrest have been unsuccessful, resuscitative hysterotomy (eg, perimortem cesarean delivery) is recommended for maternal benefit in women with a uterine size at or above the umbilicus (20 weeks of gestation or more).
- Consideration of resuscitative hysterotomy should occur as soon as there is a maternal cardiac arrest and preparations should begin in the event that return to spontaneous circulation does not occur within the first few minutes of maternal resuscitation.
- Survival curves for women and neonates have shown 50% injury-free survival rates with perimortem cesarean delivery as late as 25 minutes after maternal cardiac arrest, so even if delivery does not occur within 4–5 minutes, there still may be benefit and resuscitative hysterotomy should be considered.

The following recommendations and conclusions are based primarily on consensus and expert opinion (Level C):

- ▶ Intensive care unit admission alone is not adequate as a quality or an epidemiologic marker of maternal morbidity. However, it may be useful for local surveillance and quality assurance activities.
- ▶ Admission to the ICU should take into account objective clinical parameters that reflect instability, the potential for the patient to benefit from high acuity interventions, underlying diagnoses and prognoses, availability of clinical expertise in the current setting, and ICU beds.
- ▶ If a pregnancy is complicated by a critical illness or condition, the woman should be cared for at a hospital with obstetric services, an adult ICU, advanced neonatal care services, and appropriate hospital services such as a blood bank.
- ▶ For cases in which a higher level maternal care facility is required for critically ill women, consideration should be given to transport as soon as the need is identified and the patient is stable for transport.
- ▶ Decisions on fetal monitoring during transport should be individualized based on gestational age, maternal hemodynamic status, and feasibility of intervention in response to abnormalities in the fetal heart rate tracing.
- ▶ When obstetric patients are transferred to the ICU, patient care decisions including mode, location, and timing of delivery ideally should be made collaboratively between the intensivist, obstetrician–gynecologist, and neonatologist, and should involve the patient and her family when possible.
- ▶ Because the risk–benefit considerations for continued pregnancy versus delivery are likely to change as the pregnancy and critical illness progress, the care plan must be reevaluated regularly.
- ▶ Cesarean delivery in the ICU should be restricted to cases in which transport to the operating room cannot be achieved expeditiously and safely, or to a perimortem procedure.

For More Information

The American College of Obstetricians and Gynecologists has identified additional resources on topics related to this document that may be helpful for ob-gyns, other health care providers, and patients. You may view these resources at www.acog.org/More-Info/CriticalCareinPregnancy.

These resources are for information only and are not meant to be comprehensive. Referral to these resources

does not imply the American College of Obstetricians and Gynecologists' endorsement of the organization, the organization's website, or the content of the resource. The resources may change without notice.

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The MEDLINE database, the Cochrane Library, and the American College of Obstetricians and Gynecologists' own internal resources and documents were used to conduct a literature search to locate relevant articles published between January 1985–August 2018. The search was restricted to articles published in the English language. Priority was given to articles reporting results of original research, although review articles and commentaries also were consulted. Abstracts of research presented at symposia and scientific conferences were not considered adequate for inclusion in this document. Guidelines published by organizations or institutions such as the National Institutes of Health and the American College of Obstetricians and Gynecologists were reviewed, and additional studies were located by reviewing bibliographies of identified articles. When reliable research was not available, expert opinions from obstetrician–gynecologists were used.

Studies were reviewed and evaluated for quality according to the method outlined by the U.S. Preventive Services Task Force:

- I Evidence obtained from at least one properly designed randomized controlled trial.
- II-1 Evidence obtained from well-designed controlled trials without randomization.
- II-2 Evidence obtained from well-designed cohort or case–control analytic studies, preferably from more than one center or research group.
- II-3 Evidence obtained from multiple time series with or without the intervention. Dramatic results in uncontrolled experiments also could be regarded as this type of evidence.
- III Opinions of respected authorities, based on clinical experience, descriptive studies, or reports of expert committees.

Based on the highest level of evidence found in the data, recommendations are provided and graded according to the following categories:

Level A—Recommendations are based on good and consistent scientific evidence.

Level B—Recommendations are based on limited or inconsistent scientific evidence.

Level C—Recommendations are based primarily on consensus and expert opinion.

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