Circulation

AHA SCIENTIFIC STATEMENT

Anesthetic Care of the Pregnant Patient With Cardiovascular Disease: A Scientific Statement From the American Heart Association

This statement is endorsed by the Society for Obstetric Anesthesia and Perinatology and the Society of Cardiovascular Anesthesiologists.

The American College of Obstetricians and Gynecologists supports the value of this clinical document as an educational tool, October 2022.

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ABSTRACT: The pregnancy-related mortality rate in the United States is excessively high. The American Heart Association is dedicated to fighting heart disease and recognizes that cardiovascular disease, preexisting or acquired during pregnancy, is the leading cause of maternal mortality in the United States. Comprehensive scientific statements from cardiology and obstetrics experts guide the treatment of cardio-obstetric patients before, during, and after pregnancy. This scientific statement aims to highlight the role of specialized cardio-obstetric anesthesiology care, presenting a systematic approach to the care of these patients from the anesthesiology perspective. The anesthesiologist is a critical part of the pregnancy heart team as the perioperative physician who is trained to prevent or promptly recognize and treat patients with peripartum cardiovascular decompensation. Maternal morbidity is attenuated with expert anesthesiology peripartum care, which includes the management of neuraxial anesthesia, inotrope and vasopressor support, transthoracic echocardiography, optimization of delivery location, and consideration of advanced critical care and mechanical support when needed. Standardizing the anesthesiology approach to patients with high peripartum cardiovascular risk and ensuring that cardio-obstetrics patients have access to the appropriate care team, facilities, and advanced cardiovascular therapies will contribute to improving peripartum morbidity and mortality.

Key Words: AHA Scientific Statements ■ anesthesiology ■ cardiovascular disease ■ maternal mortality ■ obstetrics ■ patient care team ■ peripartum period

The pregnancy-related mortality rate is disconcertingly high in the United States compared with other high-income nations. In 2017, the pregnancy-related mortality ratio in the United States was 17.3 per 100 000 pregnancies compared with <10 per 100 000 in other high-income nations.[1] Cardiovascular disease (CVD) is the leading cause of maternal mortality in the United States, accounting for >25% of maternal deaths,[2] with cardiovascular maternal morbidity and mortality disproportionately affecting Black patients, who have a 3- to 4-fold higher rate of death than non-Hispanic White pregnant patients.[3] The evolving discipline of cardio-obstetrics aims to improve maternal morbidity and mortality through the multidisciplinary care of pregnant patients with congenital or acquired heart disease. The discipline seeks to improve the recognition of CVD in pregnancy and to promote multidisciplinary care coordination to mitigate peripartum and postpartum complications. The role of the anesthesiologist in a multidisciplinary pregnancy heart team is crucial to peripartum care.[4] The goal of this scientific statement is to provide a practical framework for coordinating the anesthetic care of cardio-obstetric patients undergoing delivery (Figure).

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Figure. Planning for delivery framework.
CARPREG indicates Cardiac Disease in Pregnancy; SOAP, Society for Obstetric Anesthesia and Perinatology; and WHO, World Health Organization.

PLANNING FOR DELIVERY FRAMEWORK

Who: The Patient and Pregnancy Heart Team

It is critical that the cardio-obstetrics patient undergo an individualized assessment and have a care plan developed by an expert multidisciplinary pregnancy heart team. The ROPAC cohort (Registry of Pregnancy and Cardiac Disease) includes almost 6000 pregnant patients with heart disease (2007–2018) from >60 countries. Data from ROPAC have led to numerous publications outlining specific cardiac disease processes complicating pregnancy and, in turn, has helped clinicians better guide care for these patients.[5–12] Data from ROPAC demonstrate that although rates of maternal mortality and heart failure were high among women with particular types of CVD, 9% mortality with pulmonary arterial hypertension and 11% rate of heart failure in the entire study population overall, most patients with CVD did well, suggesting that safe pregnancy can be achieved with proper care.[13] ROPAC also highlights the high rate of obstetric and fetal complications in pregnancies complicated by CVD, at 17% and 21%, respectively.[13] Expert cardio-obstetric care includes preconception counseling, risk stratification and education, multidisciplinary coordination, and careful planning guided by a multidisciplinary team.[4–11,14–16] It is reasonable for women with heart disease to be risk-stratified according to the lesion-specific Modified World Health Organization (mWHO) Pregnancy Risk Classification (Table 1), with or without consideration of other stratification tools such as the CARPREG (Cardiac Disease in Pregnancy) II risk score, which is composed of general, lesion-specific, and delivery-of-care variables.[17,18] However, risk stratification tools remain imperfect in determining absolute individual risk because they are based on population-level, often retrospective studies.[18–20] For example, although the mWHO system may be the most well-suited tool for the anesthesiologist,[15] it does not account for the magnitude of CVD (eg, valvular gradients or functional impact). Risk scoring systems are also less effective in distinguishing mild from life-threatening events that may require hospitalization or early delivery.

The pregnancy heart team is typically made up of specialists with expertise in cardiology, obstetrics, gynecology, maternal fetal medicine, primary care, nursing (specifically, critical care obstetric nurses), pharmacy, and anesthesiology. This group works together to develop an individualized antepartum, labor and delivery, and postpartum care plan for patients with CVD[4,16,21] (Table 2). Obstetric anesthesiologists have expertise in the peripartum anesthetic care of pregnant patients and are an integral part of this multidisciplinary team. The participation of cardiothoracic anesthesiologists may be useful for patients who sustain or are at risk for acute cardiovascular decompensation, potentially requiring peripartum cardiothoracic surgery or mechanical support such as extracorporeal membrane oxygenation (ECMO; Table 2). Critical care obstetric nurses are experienced obstetric nurses who have specialized critical care skills

Table 1. The Cardio-Obstetrics Patient

mWHO risk class	Cardiovascular condition	Risk (mortality and morbidity)	Considerations
Class I	Uncomplicated, small, or mild: Pulmonary stenosis Patient ductus arteriosus Mitral valve prolapse Successfully repaired simple lesions (atrial or ventricular septal defect, patent ductus arteriosus, anomalous pulmonary venous drainage) Atrial or ventricular ectopic beats, isolated	No increased risk of maternal mortality No or mild increase in morbidity	Care at local hospital Delivery at local hospital
Class II (if otherwise well and uncomplicated)	Unoperated atrial or ventricular septal defect Repaired tetralogy of Fallot Most arrhythmias Turner syndrome without congenital cardiac disease	If otherwise well, then a small increased risk of maternal mortality Moderate increase in morbidity	Care at local hospital Delivery at local hospital Pregnancy heart team consultation
Class II or III (depending on individual)	Mild LV impairment (EF >45%) Hypertrophic cardiomyopathy Native or tissue valvular heart disease not considered WHO I or IV (mild mitral stenosis, moderate aortic stenosis) Marfan syndrome or other HTAD without aortic dilation Aorta <45 mm in aortic disease associated with bicuspid aortic valve Repaired coarctation without residua (non-Turner) Atrioventricular septal defect		Pregnancy heart team consultation
Class III	Moderate LV impairment (LVEF, 30%–45%) Previous pregnancy cardiomyopathy without any residual LV impairment Mechanical valve Systemic RV with good or mildly decreased ventricular function Fontan circulation (uncomplicated) Cyanotic heart disease (unrepaired) Other complex congenital heart disease Moderate mitral stenosis Severe asymptomatic aortic stenosis Moderate aortic dilation defined as: 40–45 mm in Marfan syndrome, bicuspid aortic valve <50 mm in tetralogy of Fallot ASI 20–25 mm/m^2 in Turner syndrome Ventricular tachycardia	Significantly increased risk of maternal mortality or severe morbidity	Care at appropriate level hospital with appropriate members of the pregnancy heart team available
Class IV	Pulmonary arterial hypertension of any cause Severe systemic ventricular dysfunction (LVEF <30%, NYHA FC class III or IV) Previous peripartum cardiomyopathy with any residual impairment of LV function Severe mitral stenosis Severe symptomatic aortic stenosis Systemic RV with moderate to severely decreased LV function Severe aortic dilation defined as: >45 mm associated with Marfan syndrome >50 mm associated with bicuspid aortic valve >50 mm associated with tetralogy of Fallot ASI > 25 mm/m^2 with Turner syndrome Native severe coarctation Vascular Ehler-Danlos Fontan circulation with any complication	Extremely high risk of maternal mortality Extremely high risk of maternal morbidity Pregnancy contraindicated	Care at appropriate level hospital with appropriate members of the pregnancy heart team available

ASI indicates aortic size index; HTAD, heritable thoracic aortic diseases; LV, left ventricular; LVEF, left ventricular ejection fraction; mWHO, Modified World Health Organization; NYHA FC, New York Heart Association functional class; RV, right ventricular; and WHO, World Health Organization.

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Table 2. Members of the Pregnancy Heart Team

Core pregnancy heart team[4,16]
Cardiologist
Obstetrician
Maternal fetal medicine specialist
Anesthesiologist
Nurse specialists (critical care obstetrics nurse, intensive care nurse, obstetric nurse, lactation specialist)
Additional experts to consider when creating a pregnancy heart team[4,16,21]
Obstetric anesthesiologist
Cardiothoracic anesthesiologist
Cardiothoracic or ECMO surgeon
Other cardiovascular specialists
Heart failure
Adult congenital
Pulmonary hypertension
Electrophysiologist
Imaging specialist
Interventionalist
Intensivist
Geneticist
Neonatologist
Hematologist
Pharmacist
Pulmonologist
Perfusionist
Reasons to consult cardiothoracic anesthesiologist
Lesion triggers
Severe right- or left-sided heart failure
Systemic RV with moderate or severely decreased ventricular function
Fontan with complications
Symptomatic heart failure (especially if complicated by preeclampsia)
Severe mitral stenosis
Severe aortic stenosis
PASP >50 mm Hg, pulmonary hypertension with right heart failure, pulmonary hypertension with significant cyanosis with or without RV failure
Any unstable cardio-obstetrics patient (ie, dissecting major vessel)
Presence of major cardiovascular support device (LVAD, RVAD, ECMO)
Anticipated monitor/procedure triggers
Titration of inotropes
Need for echocardiography in management
Need for pulmonary pressure monitoring
Maternal decompensation requiring general anesthesia
Cardiothoracic surgeon or ECMO on standby
Need for combined cardiac procedure and delivery
Obstetic trigger
Heart failure with preeclampsia

ECMO indicates extracorporeal membrane oxygenation; LVAD, left ventricular assist device; PASP, pulmonary arterial systolic pressure; RV, right ventricular; and RVAD, right ventricular assist device.

and training in invasive hemodynamic monitoring and knowledge of advanced obstetric physiology and pharmacology.[22,23] Coordinating care among members of the pregnancy heart team is sometimes a delicate negotiation, and clear definition of roles and leadership is essential. Team leadership may vary over the course of the pregnancy, and the anesthesiologist may provide leadership during the peridelivery time.

What: Mode of Delivery

Medical counseling focuses on the risk of morbidity and mortality, including maternal cardiovascular, fetal, and obstetric risks, as well as management and mitigation strategies. Individualized care plans developed by the pregnancy heart team should consider the patient's underlying anatomy and physiology, access to care, delivery facility capabilities, and availability of multidisciplinary expertise. Shared decision-making is essential for all patients but especially those with the highest risk for maternal morbidity or mortality, and the patient should be engaged in discussions of all potential risks and therapeutic options.[4] These patients include those with known mWHO risk class IV lesions (Table 1).[24] The decision to continue a very high-risk pregnancy is personal to each patient and should be respected.

The pregnancy heart team should remain focused on the most appropriate mode of delivery, weighing maternal cardiovascular, fetal, and obstetric risk.[4] For patients who carry a pregnancy to near term or term, vaginal delivery is the preferred mode of delivery for most patients because it decreases the risk of obstetric complications and allows more gradual hemodynamic changes at the time of delivery, which is favorable for women with high-risk CVD. The Valsalva maneuver during vaginal delivery is reasonable for most patients with CVD. However, assistance in the second stage to avoid prolonged or forceful Valsalva may be considered in select patients with the highest risk for maternal decompensation such as those with significant ventricular dysfunction or failure, Fontan circulation, and severe pulmonary hypertension.[25] The 2 main maternal risks with the Valsalva maneuver are (1) the significant reduction in preload during Valsalva, which may not be tolerated by patients with left-sided obstructive lesions such as severe mitral stenosis, aortic stenosis, or hypertrophic obstructive cardiomyopathy, and (2) the aortic shear stress that results from the large stroke volume ejection from the previously empty, now full left ventricle. This shear stress could pose a risk to patients with underlying significant aortopathy. In general, cesarean delivery is reserved for obstetrical indications, for patients who are at a very high risk of decompensation at the time of delivery, including patients with high-risk aortopathy or maternal decompensation, or for the coordination of care in select cases. Coordination of cesarean delivery and cardiovascular procedures may be necessary in cases

in which expedited delivery allows optimal timing, hemodynamic control, and resource coordination such as the potential need for peripartum valvuloplasty or mechanical circulatory support.[24]

When: Timing of Delivery

In patients with CVD, procedures and anesthesia may pose significant risk that should be acknowledged. The timing of delivery for complex maternal CVD is not established and often debated; however, to preserve optimal newborn outcomes, the goal is to achieve 39 weeks' gestation unless there is concern for maternal or fetal decompensation.[4] Typically, delivery timing is highly individualized on the basis of the complexity and severity of the cardiovascular lesion, signs of clinical decompensation, New York Heart Association functional class, associated comorbidities, anticoagulation status, and the need for interventions that could be safely performed only in the postpartum period in the nonpregnant state.

Where: Type of Hospital and Location Within the Hospital

The American College of Obstetricians and Gynecologists and Society for Maternal-Fetal Medicine have established the Levels of Maternal Care to improve maternofetal outcomes and to reduce disparities in care by standardizing care across hospitals and enabling hospital transfers when escalation of care is necessary.[26] Maternal Level IV Care Centers are tertiary care centers with the ability to provide cardiac surgery, specialized critical care cardiology, and involvement of appropriate cardiac subspecialist experts such as pulmonary hypertension, adult congenital disease, and aortopathy specialists.

In general, patients with mWHO II classification CVD such as repaired tetralogy of Fallot and most arrhythmias can be cotreated by maternal fetal medicine specialists and a cardiology consultant and may be delivered at a local hospital.[4] However, patients with mWHO class III or higher are recommended to deliver at a Maternal Level IV Care Center, where services outside of the usual scope of labor and delivery suites can often be brought to the labor floor to optimize care. Examples of such care include continuous infusion to control an arrhythmia, the ability to initiate mechanical circulatory support, and the administration of inhaled or intravenous pulmonary vasodilators for severe pulmonary hypertension. When the support of a cardiothoracic surgeon or ECMO may be necessary, a cardiothoracic operating room or hybrid setup may be the appropriate location for cesarean delivery. The ideal location for delivery is often institution specific. Depending on locally available experts, services, and monitoring, consideration of surgical or cardiac care beds may be required for postpartum recovery in patients with high-risk and advanced cardiovascular needs.

How: Peripartum Plan

Hemodynamic Goals

Clinicians may encounter various hemodynamic changes in the postoperative and peripartum periods (Table 3). On an individual patient basis, the anesthesiologist should work with the pregnancy heart team to create a care plan specific to the cardiovascular anatomy and physiology in the context of anesthesia care for labor and delivery or cesarean delivery (Table 4).[39] When it comes to the anesthetic management, for decisions for complex critically ill patients, there is often little evidence (especially in cardio-obstetrics) to suggest that one choice is superior to another; therefore, a clinician's comfort and expertise in specific practices and modalities cannot be overstated. The peripartum care plan should be created early when possible, usually in pregnancy weeks 20 to 28, and made available in the patient's medical record that is readily accessible to all members of the pregnancy heart team to view.

Peripartum Risks

Pregnancy is a prothrombotic state, and thrombotic events contribute to major morbidity and mortality, especially in pregnant patients with CVD.[41] Anticoagulation

Table 3. Hemodynamic Changes Peripartum and Plans for Mitigation

Hemodynamic issue	Possible consequences	Plan
↑ Catecholamines (attributable to pain and anxiety)	↑ Tachycardia and arrhythmias	Avoid sudden alterations in heart rate and rhythm with neuraxial anesthesia for pain control
↓ Systemic vascular resistance (attributable to neuraxial anesthesia, pregnancy hormones, and hemorrhage)	↓ Coronary perfusion from decreased aortic diastolic pressure and increased LV end-diastolic pressure	Control sudden decreases in afterload (systemic vascular resistance) with appropriate use of vasopressors
↑ Cardiac output must increase through labor and delivery to accommodate the expected autotransfusion (preload changes)	↑ Heart failure	Support the myocardium with inotropic medications or VA ECMO Diuresis as needed
↑ Pulmonary blood flow	↑ Pulmonary pressure if pulmonary vascular resistance cannot decrease	Provide pulmonary vasodilators Control sudden changes in blood volume with diuresis
↓ Oncotic pressure	↑ Pulmonary edema	Diuresis as needed

LV indicates left ventricular; and VA ECMO, venoarterial extracorporeal membrane oxygenation.

Table 4. Unique Cardiovascular Considerations in Obstetric Anesthesia

CVD	Cardiovascular impact/hemodynamic changes	Anesthesiology considerations
HDP		
Chronic hypertension (<20 wk) Gestational hypertension (≥20 wk) Preeclampsia and preeclampsia with severe features (proteinuria, thrombocytopenia, renal insufficiency, impaired liver function, pulmonary edema, or cerebral or visual symptoms) and eclampsia	Increased afterload in the setting of uncontrolled blood pressure in pregnancy contributes to increased maternal myocardial workload and poor myocardial relaxation, along with the potential for poor placental perfusion. Preeclampsia and eclampsia remain part of the spectrum of PPCM.[27] Chronic and gestational hypertension may be treated expectantly with pregnancy-safe medical therapy. Preeclampsia and eclampsia require a more urgent approach that considers timing of delivery, fluid management, seizure prevention, lowering of blood pressure, and prevention of end-organ damage.	Hemodynamic goals: reduce systemic vascular resistance Anesthetic plan: neuraxial anesthesia Hemodynamic medication plan: antihypertensive medication Access: usual large-bore peripheral intravenous line Monitoring: consider arterial line if severe hypertension requires continuous intravenous medication, or if noninvasive measurements are inaccurate, consider transthoracic echocardiography or point-of-care cardiac ultrasound Postpartum hemorrhage prevention and management: avoid methylergonovine Special considerations: monitor for thrombocytopenia, liver dysfunction, coagulopathy, and myocardial dysfunction Recovery: usual care
Cardiomyopathy with severe LV systolic dysfunction		
Increased-risk conditions*: Systemic RV Any systemic ventricular systolic dysfunction High-risk conditions†: Systemic ventricular EF <30% Systemic ventricular dysfunction with NYHA FC III–IV	Patients with severe systolic dysfunction or elevated NYHA FC are at highest risk for low cardiac output and cardiogenic shock, and pregnancy is generally contraindicated. In those with prior PPCM, there is high risk for worsening LV dysfunction and ≈19% risk of death in SSP if the recovered LVEF is <50%.[28] Young patients with cardiomyopathy may appear clinically well until late in pregnancy because of robust compensatory mechanisms. Medical heart failure therapies may include β-blockers and afterload reduction (excluding ACE inhibitors, ARBs, ARNI).	Hemodynamic goals: maintain normal sinus rhythm, augment contractility to maintain cardiac output Anesthetic plan: carefully titrated neuraxial anesthesia Hemodynamic medication plan: inotropic medications Access: usual large-bore peripheral intravenous line; consider central venous access (peripheral or central insertion) Monitoring: consider arterial line; consider transthoracic echocardiography or point-of-care cardiac ultrasound Postpartum hemorrhage prevention and management: usual care Special considerations: in patients with low cardiac output, severe right-sided heart dysfunction, systemic RV, or ensuing shock, inotropes, mechanical circulatory support, or ECMO may be considered Recovery: consider intensive care unit
Valvular heart disease		
Stenotic valve disease	Left-sided valvular obstruction limits the ability to provide adequate cardiac output in the setting of the low-SVR state of pregnancy. Severe mitral stenosis and severe symptomatic aortic stenosis remain high-risk lesions for which pregnancy is contraindicated. Patients with severe left-sided heart obstruction are at risk of poor cardiac output, congestion, heart failure, and arrhythmia; postdelivery autotransfusion may exacerbate this physiology.	Hemodynamic goals: maintain aortic diastolic blood pressure at baseline, normal sinus rhythm Anesthetic plan: carefully titrated neuraxial anesthesia Hemodynamic medication plan: vasopressor medications Access: usual large-bore peripheral intravenous line Monitoring: consider arterial line for severe stenotic lesions; consider transthoracic echocardiography or point-of-care cardiac ultrasound Postpartum hemorrhage prevention and management: usual care Recovery: consider intensive care unit for high risk
Regurgitant valve disease	Regurgitant valve disease is typically better tolerated than stenosis, but chamber dilatation may occur.	Hemodynamic goals: avoid hypertension and bradycardia Anesthetic plan: neuraxial anesthesia Hemodynamic medication plan: consider vasopressor medications with chronotropic properties, inotropic medications Access: usual large-bore peripheral intravenous line Monitoring: usual care; consider transthoracic echocardiography or point-of-care cardiac ultrasound Postpartum hemorrhage prevention and management: usual care Recovery: usual care

(*Continued*)

Table 4. Continued

CVD	Cardiovascular impact/hemodynamic changes	Anesthesiology considerations
Aortopathy		
Increased-risk conditions*: Marfan syndrome with aorta 45–50 mm Bicuspid aortic valve with aorta 45–50 mm High-risk conditions†: Marfan syndrome with aorta >45 mm Bicuspid aortic valve with aorta >50 mm Elevated risk, poorly defined magnitude: Loeys-Dietz syndrome Vascular Ehlers-Danlos syndrome Genetic-negative HTAAD/S	The hemodynamic and hormonal changes of pregnancy affect the integrity of the arterial vasculature and are an important risk factor for dissection, especially in patients with connective tissue disease.[29,30] Patients with vascular connective tissue disease are also often at increased risk for obstetric and neonatal events. For some types of aortopathy, prophylactic aortic root replacement is advised to avoid spontaneous dissection; however, the impact during pregnancy is less clear but likely includes consideration of absolute diameter and cross section–to–height ratio.[31] Pharmacological therapy with β-blockers is often used in both pregnant and nonpregnant states.	Hemodynamic goals: avoid increases in sheer stress within the aorta and increased systemic vascular resistance Anesthetic plan: carefully titrated neuraxial anesthesia Hemodynamic medication plan: vasodilator medications Access: usual large-bore peripheral intravenous line Monitoring: consider arterial line if severe hypertension requires continuous intravenous medication; if noninvasive measurements are inaccurate, consider transthoracic echocardiography or point-of-care cardiac ultrasound Postpartum hemorrhage prevention and management: avoid methylergonovine Special considerations: may choose to perform cesarean delivery in a cardiothoracic operating room for highest-risk patients; specialized monitoring at the time of labor and delivery is often required and includes close watch over blood pressure and heart rate, with a low threshold to use 3D imaging if there is chest pain or other signs of dissection. Recovery: consider intensive care unit if high risk
CHD		
Increased-risk conditions*: Morphological RV in systemic position Fontan circulation Unrepaired cyanotic heart disease Other complex CHD High-risk conditions†: CHD with pulmonary hypertension Eisenmenger syndrome (right-to-left shunt) Native severe coarctation	The risk of pregnancy in CHD is determined by (1) the original congenital heart lesion and (2) intervention/surgical history. This risk can be affected by the development of subsequent acquired CVD such as heart failure or arrhythmia. A few types of CHD involve a morphological RV placed in the systemic ventricular position (D-TGA after atrial switch and CCTGA). Patients with unrepaired cyanotic CHD or Fontan circulation are at increased risk for maternal cardiovascular events, specifically heart failure and arrhythmia, in addition to obstetric events such as postpartum hemorrhage.[32] Patients with CHD-associated pulmonary hypertension or Eisenmenger syndrome have extremely high mortality risk, estimated to be up to 40%.[33]	Hemodynamic goals: In Eisenmenger's specifically, the inability to lower high PVR leads to an increase in right-to-left shunting. The increased shunt, combined with increased oxygen consumption in pregnancy, results in cardiopulmonary decompensation, typically starting in the second to third trimester. In right-to-left shunts, cardiac output can be augmented by further increasing the right-to-left blood flow, and as a result, physiology that results in lowering SVR (ie, bleeding, dehydration) may present initially as worsening hypoxia that does not correct with peripheral oxygen administration. Anesthetic plan: carefully titrated neuraxial anesthesia Hemodynamic medication plan: will vary according to disease Access: usual large-bore peripheral intravenous line; consider central venous access in severe, unrepaired, or decompensated conditions Monitoring: consider arterial line; consider transthoracic echocardiography or point-of-care cardiac ultrasound Postpartum hemorrhage prevention and management: usual care, avoid methylergonovine and carboprost if concurrent pulmonary hypertension is present Special considerations: may choose to perform cesarean delivery in a cardiothoracic operating room for highest-risk patients; in patients with low cardiac output, severe right-sided heart dysfunction, systemic RV, or ensuing shock, inotropes, mechanical circulatory support, or ECMO may be considered Recovery: consider intensive care unit
Pulmonary hypertension		
WHO group 1 disease† Non–WHO group 1 disease	In patients with WHO group 1 PAH not on medical therapy, mortality is high (>50%).[34] However, with newer directed medical therapy, it is likely to be in the low double digits.[13] Increased maternal morbidity and mortality occur most commonly as a result of RV failure and shock[35] precipitated by: Shifts in RV preload Inability to adequately lower PVR to increase cardiac output Changes in RV preload caused by blood loss and autotransfusion during delivery	Anesthetic plan: carefully titrated neuraxial anesthesia Hemodynamic medication plan: pulmonary vasodilator and inotropic medications Access: usual large-bore peripheral intravenous line; consider central venous access (peripheral or central insertion); consider pulmonary artery catheter Monitoring: consider arterial line; consider transthoracic echocardiography or point-of-care cardiac ultrasound Postpartum hemorrhage prevention and management: avoid methylergonovine and carboprost Special considerations: may choose to perform cesarean delivery in a cardiothoracic operating room for highest-risk patients. In patients with severe pulmonary hypertension, Eisenmenger syndrome, low cardiac output, severe right-sided heart dysfunction, systemic RV, or ensuing shock, inotropes, mechanical circulatory support, or ECMO may be considered. Recovery: consider intensive care unit

(*Continued*)

Table 4. Continued

CVD	Cardiovascular impact/hemodynamic changes	Anesthesiology considerations
Ischemic heart disease		
Coronary artery disease SCAD	Patients with underlying atherosclerotic coronary disease are at increased risk for myocardial ischemia associated with the physiological changes in pregnancy. Depending on the degree of ischemia present, cardiac arrest, ACS, arrhythmia, or heart failure may result (≈10% of pregnancies) and should be monitored for throughout pregnancy and postpartum.[36] Preeclampsia and low birth weight have been shown to be more common in patients with atherosclerotic disease or diabetes. Neonatal events were also more frequent in patients with underlying coronary disease (up to 30%).[36] SCAD occurs in patients without nonatherosclerotic coronary disease and remains the most common cause of ACS in pregnant patients.[37] SCAD was most common 18 wk after conception in a large case-control study.[38] Potential risk factors for SCAD should be recognized: hypertension or vascular disease such as fibromuscular dysplasia or connective tissue disease. It is important to recognize that patients with SCAD, like those with atherosclerotic coronary disease, are at risk for heart failure, arrhythmia, and cardiac arrest. However, most patients with SCAD tolerate the remainder of pregnancy and lactation; it is important to note that the risk for recurrent SCAD has not been shown to be higher in SSPs for patients with SCAD.[38]	Hemodynamic goals: maintain normal sinus rhythm, aortic diastolic blood pressure, and cardiac output Anesthetic plan: carefully titrated neuraxial anesthesia Hemodynamic medication plan: vasopressor medication, inotrope medication, nitroglycerine Access: usual large-bore peripheral intravenous line; consider central venous access (peripheral or central insertion) if low cardiac output Monitoring: consider arterial line; consider transthoracic echocardiography or point-of-care cardiac ultrasound Postpartum hemorrhage prevention and management: avoid methylergonovine Special considerations: may choose to perform cesarean delivery in a cardiothoracic operating room for highest-risk patients. In patients with low cardiac output, severe right-sided heart dysfunction, or ensuing shock, inotropes, mechanical circulatory support, or ECMO may be considered. Recovery: consider intensive care unit

ACE indicates angiotensin-converting enzyme; ACS, acute coronary syndrome; ARB, angiotensin receptor blocker; ARNI, angiotensin receptor-neprilysin inhibitor; CCTGA, congenitally corrected transposition of the great arteries; CHD, congenital heart disease; CVD, cardiovascular disease; D-TGA, dextro-transposition of the great arteries; ECMO, extracorporeal membrane oxygenation; EF, ejection fraction; HDP, hypertensive disorders of pregnancy; HTAAD/S, heritable thoracic aortic aneurysm disease/syndrome; LV, left ventricular; LVEF, left ventricular ejection fraction; NYHA FC, New York Heart Association functional class; PAH, pulmonary arterial hypertension; PPCM, peripartum cardiomyopathy; PVR, pulmonary vascular resistance; RV, right ventricle; SCAD, spontaneous coronary artery dissection; SSP, subsequent pregnancy; SVR, systemic vascular resistance; 3D, 3-dimensional; and WHO, World Health Organization.

*Increased-risk conditions indicate WHO risk class III lesions.

†High-risk conditions indicate WHO risk class IV lesions.[15,16]

can affect the timing and safety of neuraxial anesthesia. Therefore, the pregnancy heart team should be involved in decisions on peripartum anticoagulation. To avoid spinal-epidural hematoma, neuraxial techniques should be timed according to the anticoagulation medication and dose as recommended by the American Society of Regional Anesthesia and Pain Medicine guidelines and the Society for Obstetric Anesthesia and Perinatology consensus statement (Table 5).[42,43] The anesthesiologist can help coordinate the timing of stopping anticoagulation with the obstetrician and cardiologist if neuraxial anesthesia is planned or advise in the setting of full anticoagulation (mechanical heart valves) if general anesthesia will be necessary. The anticoagulation strategy should also include a plan for any event that may lead to early or unplanned delivery.

ANESTHESIA FOR VAGINAL DELIVERY

A vaginal delivery with effective neuraxial analgesia is the preferred mode of delivery for most patients with CVD.[4] Compared with cesarean deliveries, vaginal deliveries are associated with less blood loss, fewer wound infections, and fewer thromboembolic events.[44–46] Neuraxial labor analgesia decreases maternal plasma epinephrine and norepinephrine during labor.[47] Therefore, it is reasonable to place the epidural catheter at the onset of labor discomfort. An added benefit of an epidural catheter is that it provides a conduit for conversion to surgical anesthesia should emergency cesarean be necessary. It is recommended that an epidural catheter be promptly replaced if it no longer provides sufficient labor analgesia.[39]

Neuraxial catheters for labor analgesia may be placed by an epidural, dural puncture epidural, or combined spinal-epidural (CSE) technique. When an epidural catheter is placed with the loss-of-resistance technique, the use of saline rather than air may decrease the risk of venous air embolism in the event of intravascular needle placement. This is especially important in patients with intracardiac shunt lesions in whom the risk of paradoxical embolism exists.[48,49] In patients with CVD, consideration should be given to the risks and benefits of a traditional epidural test dose. In patients who could decompensate from intravascular epinephrine or the rapid onset of a spinal anesthetic, the test dose could be divided into 2 separate intravascular

Table 5. Summary of American Society of Regional Anesthesia and Pain Medicine Guidelines and the Society for Obstetric Anesthesia and Perinatology Consensus Statement

Heparin	Dose	Timing	Recommendations[39,42,43]
Subcutaneous unfractionated heparin	Low dose: 5000 U 2–3 times daily	≥4–6 h from last dose	Likely low risk to proceed with neuraxial
	Low dose: 5000 U 2–3 times daily	<4–6 h from last dose	If activated partial thromboplastin time within normal range or anti–factor Xa level undetectable, then likely low risk to proceed with neuraxial
	Intermediate dose: (7500 or 10 000 U twice daily)	≥12 h from last dose	If activated partial thromboplastin time within normal range or anti–factor Xa level undetectable, then likely low risk to proceed with neuraxial
	Intermediate dose: (7500 or 10 000 U twice daily)	<12 h from last dose	Wait 12 h from last dose and then proceed as above
	High dose: any individual dose >10 000 U or total daily dose >20 000 U	≥24 h from last dose	If activated partial thromboplastin time within normal range or anti–factor Xa level undetectable, then likely low risk to proceed with neuraxial
	High dose: any individual dose >10 000 U or total daily dose >20 000 U	<24 h	Minimal data to guide risk assessment; therefore, wait 24 h from last dose and then proceed as above
Subcutaneous low-molecular-weight heparin	Low dose: enoxaparin ≤40 mg once daily or 30 mg twice daily		Wait 12 h after dose
	Intermediate (eg, enoxaparin >40 mg once daily and <1 mg/kg) or high dose (enoxaparin 1 mg/kg twice daily or 1.5 mg/kg once daily)		Wait 24 h after dose

and intrathecal tests. This can involve (1) administering fentanyl 50 µg through the epidural catheter while asking the patient to report symptoms of intravascular opioid administration and (2) administering a low-dose local anesthetic solution (eg, bupivacaine 0.0625%–0.125%) through the epidural catheter while asking the patient to report with motor and sensory assessments. If a CSE technique is used for labor analgesia, lower doses of intrathecal medications such as bupivacaine 2 mg combined with fentanyl 10 µg can be used. Regardless of the technique used to place the epidural catheter, slow aspiration with a low-volume syringe (1–3 mL) can be useful for detecting an inadvertent intrathecal or intravascular catheter. In cardiac patients, the initial labor analgesia epidural medication should be titrated slowly, over 10 to 20 minutes, with careful monitoring of vital signs and sensory and motor block to detect a misplaced catheter and to provide time to prevent and treat hypotension. Labor analgesia may be maintained with standard local anesthetic and opioid infusions (eg, bupivacaine 0.0625%–0.125% with 1–2 µg/mL fentanyl), through either patient-controlled continuous epidural medication infusions or programmed intermittent boluses. Either mode may be accompanied by patient-controlled epidural boluses.

Regardless of the technique used to initiate neuraxial anesthesia, maintaining hemodynamic afterload at baseline is essential for maintaining coronary perfusion, particularly in patients with left ventricular hypertrophy, left ventricular outflow tract obstruction, stenotic valvular lesions, or pulmonary hypertension. Intra-arterial pressure monitoring may be useful to monitor and promptly treat maternal blood pressure deviations from baseline. For patients with CVD who are at risk for pulmonary edema, it may be reasonable for the anesthesiologist to avoid a prophylactic routine fluid bolus before the initiation of neuraxial labor analgesia. At the onset of neuraxial analgesia, maternal hypotension should be treated with vasopressor support to maintain maternal blood pressure at baseline. Small amounts of crystalloid supplementation (eg, 200 mL) may be used to treat mild hypotension, but vasopressor support should be the mainstay for augmentation of systemic vascular resistance and maternal blood pressure should it decrease as a result of neuraxial anesthesia. It is routine for patients to require small doses of intravenous phenylephrine (eg, 50–100 µg) or intravenous ephedrine (eg, 5–10 mg) to augment systemic vascular resistance. A continuous phenylephrine infusion can be used as necessary in laboring patients to maintain maternal blood pressure at baseline. Other vasopressors such as norepinephrine or vasopressin and inotropic medications such as dobutamine, dopamine, milrinone, or epinephrine may be administered less routinely during vaginal delivery as determined by the patient's clinical status. For patients with an intracardiac shunt, in whom low afterload may lead to hypoxemia, it is critical for the anesthesiologist to rapidly correct decreases in afterload with vasopressor support.

ANESTHESIA FOR CESAREAN DELIVERY

Neuraxial anesthesia is typically preferred for cesarean delivery, including for patients with mWHO class III or IV lesions, although the choice of anesthetic technique should be individualized to the patient with the anesthesiologist.[50,51] Potential indications for proceeding with general anesthesia include cardiopulmonary decompensation necessitating intubation or a contraindication to neuraxial anesthesia such as current anticoagulation, severe thrombocytopenia, or maternal refusal of neuraxial

anesthesia.[42,43] In patients at risk for decompensated heart failure, there is a theoretical concern for hemodynamic decompensation immediately after delivery because of the sudden autotransfusion that occurs with aortocaval decompression and uterine involution at the time of delivery. If a patient with CVD is dyspneic or hypoxemic and cannot lie supine before cesarean delivery, then general anesthesia with intubation may be indicated to prepare for potential cardiopulmonary decompensation immediately after delivery. In such cases, continuous venous and arterial monitoring is used to identify and manage rapidly changing hemodynamic status attributable to volume shifts. The hemodynamic changes from the onset of a spinal anesthetic for cesarean delivery are more rapid and pronounced than for a slowly dosed (over 15–20 minutes) epidural anesthetic.[52] Patients with mWHO class I or II cardiac disease typically tolerate a traditional intrathecal dose of local anesthesia (eg, hyperbaric bupivacaine 10–15 mg) for cesarean delivery. Depending on the cardiovascular lesion, patients with mWHO class III or IV lesions may benefit from a more gradual-onset sympathectomy. Options include an epidural technique, a CSE technique with intrathecal opioids and epidural local anesthetic, or a sequential CSE technique in which intrathecal opioids and low-dose bupivacaine (2.5–5 mg) are administered, followed by a slow epidural medication titration of local anesthetic, typically 2% lidocaine to a T4 to T6 surgical level.[53] The sequential CSE technique theoretically combines the greater block reliability, symmetry, and consistency of intrathecal local anesthesia with the more gradual-onset sympathectomy of epidural local anesthesia.

At the time of the surgical block placement, it is reasonable to minimize the crystalloid fluid coload in patients at risk for pulmonary edema. It may also be beneficial to initiate the titration of a prophylactic vasopressor to maintain systemic vascular resistance and blood pressure at maternal baseline so as to maintain coronary perfusion regardless of the neuraxial technique used to achieve adequate anesthesia.[54–56] For example, phenylephrine (eg, starting titration at 0.5–0.75 $\mu g \cdot kg^{-1} \cdot min^{-1}$) or norepinephrine (eg, starting titration at 0.05–0.075 $\mu g \cdot kg^{-1} \cdot min^{-1}$) infusion can be initiated through a peripheral intravenous line on completion of the neuraxial block and titrated to maintain a heart rate >60 bpm and a mean arterial pressure near baseline.[57,58]

ACCESS, MONITORING, AND ECHOCARDIOGRAPHY

Monitoring during a cesarean delivery includes standard American Society of Anesthesiology monitors and often intra-arterial blood pressure monitoring.[59] The beat-to-beat blood pressure measurements assist in titration of vasopressors (phenylephrine, norepinephrine, or ephedrine) during induction of a neuraxial or general anesthetic. Maternal heart rate and systemic arterial pressures should be monitored throughout labor and delivery with a special focus during induction of neuraxial or general anesthesia, second and third stages of labor, cesarean delivery, or a postpartum hemorrhage. Intra-arterial blood pressure monitoring is often used in patients with specific cardiac lesions, most of which are classified as mWHO class III or IV. Pulse oximetry and continuous electrocardiographic monitoring should be considered in all patients with CVD. Central venous and pulmonary artery pressure monitoring is reserved for patients with cardiopulmonary decompensation or right ventricular failure requiring titration of vasopressors and pulmonary vasodilators, as well as those who may be subject to large volume shifts. Peripherally inserted central venous catheters can be useful in patients in whom prolonged central access may be necessary or in whom access may be difficult. Pulmonary artery catheters are not commonly used as cardiac output monitors in pregnant patients and may lead to complications such as arrhythmias and, rarely, bleeding and thromboembolic events.[60] Therefore, pulmonary artery catheters are generally deferred unless there is a need for cardiopulmonary bypass or for continuous pulmonary pressure or cardiac output monitoring of patients with moderate or severe pulmonary hypertension or patients with severely reduced ventricular function in the intensive care unit postpartum.[60,61] When needed and when resources are available, less invasive monitoring such as bedside transthoracic echocardiography can be used for cardiac function and output assessment.

Focused cardiac ultrasound can be performed at the bedside to assist in treatment of the cardio-obstetric patient. It is a safe modality that can provide expedited answers to many clinical questions.[62] The use of focused cardiac ultrasound is associated with a significant reduction in time to diagnosis and treatment.[63] In the obstetric patient, cardiac ultrasound can assess (1) volume status to help guide fluid administration or diuresis, (2) left and right ventricular global function, (3) regional wall abnormalities, (4) pericardial effusions, (5) valvular status (regurgitation or stenosis), and (6) changes in the proximal ascending aorta. In the obstetric patient, the gravid uterus displaces the heart laterally and upward in the chest such that the parasternal views are relatively easy to obtain. The apical views can also generally be obtained easily in pregnant patients, whereas the subcostal views may be more challenging. Transesophageal echocardiography may be useful in the care of the patient under general endotracheal anesthesia if transthoracic imaging is not adequate.

EXTRACORPOREAL MEMBRANE OXYGENATION

ECMO is an important last line of support for acute respiratory failure, ventricular failure, or cardiovascular decompensation. ECMO circuits consist of a venous

drainage cannula, usually inserted peripherally, a centrifugal pump, a gas exchanger, and a reinfusion cannula inserted either into the jugular or femoral vein for venovenous ECMO or into the femoral artery for venoarterial ECMO. Venovenous ECMO may be necessary to treat refractory hypoxia, especially in the case of respiratory failure attributable to viral infections or increased shunting. Venoarterial ECMO effectively offloads the right ventricle and is ideal for supporting patients with acutely worsened pulmonary hypertension or patients with severely reduced ventricular function refractory to medical management. If the use of ECMO is anticipated, a perfusionist and surgeon should be notified so that they can be available. The insertion of small placeholder sheaths (5F) in the femoral vein and artery before any procedures can facilitate rapid cannulation for ECMO.

Previously reported cases of successful resuscitation with ECMO after peripartum cardiac arrest indicate that deployment of an ECMO team, if available, early in a maternal cardiac arrest can be lifesaving.[64] In reported cases of maternal arrest when ECMO was used, 87.7% of resuscitations were successful compared with only 58.9% resuscitation success across all maternal arrests when ECMO may not have been used.[64,65] In a systematic review of ECMO use in pregnancy, the most common antepartum indications for ECMO were adult respiratory distress syndrome (65.4%), cardiac failure (9.9%), and pulmonary hypertension (8.6%). The immediate postpartum indications (within 24 hours of delivery) were cardiac arrest (56.6%), cardiac failure (23.2%), and amniotic fluid embolism (21.7%). Indications for ECMO >24 hours after delivery but within 42 days of delivery included adult respiratory distress syndrome (39.7%), peripartum cardiomyopathy (25.4%), and cardiac failure (19%).[64]

POSTPARTUM HEMORRHAGE PREVENTION AND MANAGEMENT

Patients with heart disease are at increased risk for postpartum hemorrhage.[66,67] Hemorrhagic shock in the setting of CVD may initiate rapid hemodynamic deterioration. Therefore, early active management of the third stage of labor and prevention of uterine atony and hemorrhage are essential. In patients with CVD undergoing cesarean delivery, prophylactic oxytocin should be titrated with an infusion pump immediately after delivery. Bolus dosing or overdosing can rapidly decrease systemic vascular resistance.[68] Doses of oxytocin greater than the ED95 (16.2 IU/h in nonlaboring patients undergoing cesarean section and 44.2 IU/h in laboring patients undergoing cesarean delivery) generally do not provide improved uterine tone and increase the incidence of side effects.[69,70] The cardio-obstetrics team must consider the side effects of second-line uterotonic agents (eg, carboprost and methylergonovine) in the setting of CVD.

Carboprost increases pulmonary vascular resistance and pulmonary artery pressures significantly. Carboprost has been described as precipitating bronchospasm, abnormal ventilation perfusion ratios, increased intrapulmonary shunt fraction, hypoxemia, and death.[71–74] Methylergonovine causes vascular smooth muscle contraction and increases systemic vascular resistance.[75] In a large retrospective cohort of all women (not specifically those with CVD), methylergonovine did not appear to cause myocardial ischemia and was associated with reduced risk of hemorrhage-related morbidity.[75,76] Therefore, some may argue that in the setting of hemorrhage, especially with limited resources, contraindications to uterotonic drugs may be considered relative. Misoprostol is generally considered to have few cardiovascular side effects, although it is considered less therapeutically effective compared with oxytocin, methylergonovine, and carboprost.[77]

Because of the systemic side effects of uterotonics, there should be early consideration of obstetric maneuvers in addition to medical uterotonics such as uterine massage, prompt surgical management, uterine compression sutures, and Bakri balloon placement. Rectal misoprostol may be placed prophylactically after delivery. In the setting of massive hemorrhage, large-volume transfusion may be required, and point-of-care cardiac ultrasound may be particularly useful in these cases for volume and myocardial function assessment. Early evaluation for and use of venoarterial ECMO may be lifesaving in cases of massive hemorrhage in patients with severe or decompensated cardiac disease or can be used if myocardial failure results from hypovolemic arrest while the team is providing fluid and appropriate transfusion resuscitation.

According to the World Health Organization, in addition to standard care, tranexamic acid (TXA), an antifibrinolytic agent, may be considered in the early treatment (within 3 hours of birth) of postpartum hemorrhage after delivery by either vaginal birth or cesarean delivery when initial medical therapy fails. TXA should be avoided in patients with a known contraindication to antifibrinolytic therapy such as thromboembolic disease during pregnancy.[78] The WOMAN trial (World Maternal Antifibrinolytic), an international, randomized, double-blind, placebo-controlled trial of 20 060 women with postpartum hemorrhage, showed a reduction in death attributable to bleeding in women treated with TXA and demonstrated no significant increase in thromboembolic events (pulmonary embolism, deep vein thrombosis, myocardial infarction, and stroke) compared with placebo.[79] Randomized trial data on the use of TXA in those with coronary stents or after cardiac arrest are lacking; however, there are case reports in nonobstetric patients of stent thrombosis with TXA use.[80] TXA should be used with caution in the presence of coronary stents.

SPECIAL MEDICATION CONSIDERATIONS

Many obstetric medications have cardiovascular consequences. Magnesium sulfate can lead to hypotension. Terbutaline causes tachycardia and increases myocardial contractility. Oxytocin decreases systemic vascular resistance.[68]

RECOVERY CARE

The postpartum period, specifically the first 24 to 48 hours after delivery, is associated with significant hemodynamic changes and fluid shifts, which may precipitate heart failure and arrhythmias.[18] However, in women at high risk of maternal cardiovascular decompensation, no formal guidelines suggest the appropriate duration of intensive care unit stay or monitored observation after delivery. Therefore, the level of postpartum care should be individualized to the patient's current clinical status, incorporating the unique monitoring and therapeutic needs and the ability to provide these resources in the current setting. Staffing models, physical design of the unit, experience, and access should be considered in the creation of care and recovery plans. The unit location and nursing staff (obstetric, critical care obstetric, or intensive care nurses) for postpartum patients with cardiac disease should be selected according to the type and severity of CVD, the obstetric and cardiopulmonary clinical acuity, and the advanced cardiac monitoring requirements unique to each patient. The immediate postpartum recovery period should include frequent assessment of the breasts for symmetry, redness, engorgement, and pain; the uterus for placement and tone; the bladder for distention; the bowel for sounds of intestinal motility; lochia for amount, clots, color, and odor; lacerations or episiotomy for signs of inflammation or infection; the lower extremities for signs of thrombophlebitis, including swelling, redness, and pain; and emotions or signs of postpartum mood disorders.

Continuous bedside nursing care with ready access to obstetric anesthesia, maternal fetal medicine, and cardiac teams should be available. Intensive care units can be used for skill of nursing and frequency of monitoring in patients who are at the highest risk of postpartum complications such as arrhythmias and heart failure.[18] Patients who recover off the labor and delivery unit must have the usual frequency of examinations by obstetricians and obstetric nurses to ensure adequate uterine tone and minimal postpartum bleeding.

SPECIAL SITUATIONS

1. Urgent evaluation: Several initiatives exist to help clinicians identify early warning signs of undiagnosed or new-onset CVD in pregnancy.[4] Distinguishing between signs and symptoms of normal pregnancy and those of heart disease can be challenging but can be achieved through proper evaluation (Table 6). The American College of Obstetricians and Gynecologists and the California Maternal Quality Care Collaborative recommend prompt evaluation for any pregnant patient with a heart rate ≥120 bpm, oxygen saturation ≤95%, respiratory rate ≥25 breaths/min, systolic blood pressure ≥160 mm Hg, and shortness of breath at rest or with minimal exertion.[4]
2. Arrhythmia: Arrhythmia may be the initial presentation of cardiac disease in pregnancy or a complication that develops as a result of atrial stretch from the increased circulating blood volume of pregnancy. Most arrhythmias in pregnancy are asymptomatic or benign, do not lead to hemodynamic instability, and do not require treatment. The most common arrhythmias in pregnancy are premature atrial beats, premature ventricular beats, sinus tachycardia, and sinus arrhythmia.[82] Rarely, arrhythmias lead to hemodynamic compromise, requiring either pharmacological or electric urgent intervention.[82] Because of teratogenic effects during the first trimester, many antiarrhythmic medications are not recommended during pregnancy. Metoprolol, propranolol, sotalol, verapamil, procainamide, flecainide, propafenone, and digoxin are generally safe and well tolerated in pregnant patients.[82] If hemodynamically stable supraventricular tachycardia cannot be treated conservatively with vagal maneuvers (carotid sinus massage and Valsalva maneuver), intravenous adenosine is safe in pregnancy,[82] as is electric cardioversion.[16,82,83] Fetal monitoring is suggested before and after cardioversion because there is a small risk of fetal arrhythmia. Unstable sustained ventricular tachycardia should be immediately treated with electric cardioversion.[16,82]
3. Maternal cardiac arrest: Maternal cardiac arrest occurs in 1 in 12 000 delivery hospitalizations or 8.5 per 100 000 deliveries.[65] Maternal CVD is the second leading cause of maternal arrest in the United States. The top 4 causes include hemorrhage (38.1%), heart failure or myocardial infarction (15.2%), amniotic fluid embolism (13.3%), and sepsis (11.2%).[65] In the event of a maternal cardiac arrest, the anesthesiologist has multiple roles as code team leader and is a critical resource for performing code tasks.[65,84] Hence, it is essential to highlight here the cautionary statement from the "Society for Obstetric Anesthesia and Perinatology Consensus Statement on the Management of Cardiac Arrest in Pregnancy": "The code leader should not be task saturated, and should be able to direct interventions, communicate effectively, and periodically reassess management goals and outcomes."[84] A comprehensive review of the care required during a maternal arrest is beyond the scope of this scientific statement. Updated algorithms are available and should be used at the time

Table 6. How to Differentiate Common Signs and Symptoms of Normal Pregnancy From Those That Are Abnormal and Indicative of Underlying Cardiac Disease

		Routine care	Caution*†	Stop†‡
		Reassurance	Nonemergency evaluation	Prompt evaluation by pregnancy heart team
History of CVD		None	None	Yes
Self-reported symptoms		None or mild	Yes	Yes
	Shortness of breath	No interference with activates of daily living; with heavy exertion only	With moderate exertion, new-onset asthma, persistent cough, or moderate or severe OSA§	At rest; paroxysmal nocturnal dyspnea or orthopnea; bilateral chest infiltrates on CXR or refractory pneumonia
	Chest pain	Reflux related that resolves with treatment	Atypical	At rest of with minimal exertion
	Palpitations	Few seconds, self-limited	Brief, self-limited episodes; no light-headedness or syncope	Associated with near syncope
	Syncope	Dizziness only with prolonged standing or dehydration	Vasovagal	Exertional or unprovoked
Vital signs		Normal		
	HR, bpm	<90	90–119	≥120
	Systolic BP, mm Hg	120–139	140–159	≥160 (or symptomatic low BP)
	RR, breaths per min	12–15	16–25	≥25
	Oxygen saturation, %	>97	95–97	<95 (unless chronic)
Physical examination		Normal		
	JVP	Not visible	Not visible	Visible >2 cm above clavicle
	Heart	S3, barely audible soft systolic murmur	S3, systolic murmur	Loud systolic murmur, diastolic murmur, S4
	Lungs	Clear	Clear	Wheezing, crackles, effusion
	Edema	Mild	Moderate	Marked

BP indicates blood pressure; CVD, cardiovascular disease; CXR, chest x-ray; HR, heart rate; JVP, jugular venous pressure; OSA, obstructive sleep apnea; and RR, respiratory rate.

*If unclear, any combination of factors in the Caution column that add up to ≥4 should prompt further evaluation.

†Data in this column are from Hameed et al.[81]

‡History of CVD or signs and symptoms in the Stop column should lead to urgent evaluation by the pregnancy heart team.

§Should raise concern about heart failure and should promptly be evaluated.

of arrest to ensure that all steps are performed rapidly with consideration given to the changes in cardiopulmonary resuscitation and differential diagnosis of arrest cause in the obstetric patient.[84–86] Briefly, cardiopulmonary resuscitation should be performed as usual with similar compression ventilation ratios, application of backboard, airway support, medications, dosages, and defibrillation as necessary.[84,85] Key differences in the pregnant patient include preparations for fetal delivery parallel to the maternal resuscitative efforts, application of left lateral uterine displacement, avoidance of nasal airways, placement of intravenous access above the diaphragm, and need for neonatology team for fetal resuscitation and surgical or obstetric team to perform perimortem cesarean delivery.[84,85] A perimortem cesarean delivery (also called a resuscitative hysterotomy) should be performed at the site of maternal cardiac arrest within 4 to 5 minutes should there be no return of spontaneous circulation in which the uterus extends to or above the umbilicus (≈20 weeks of gestation or greater).[84,85,87] If available, we encourage the early use of venoarterial ECMO and transesophageal echocardiography when indicated in the setting of maternal arrest.[64]

SPECIFIC DISEASE CONSIDERATIONS

CVDs that affect pregnancy encompass a diverse group of unique diagnoses that result in distinct maternal hemodynamic changes superimposed on the dynamic variations expected throughout pregnancy and labor and delivery. In short, no 2 cardiac disease states look the same in a pregnant woman. Common CVD states and the hemodynamic impact on the pregnant patient should be considered in the creation of the anesthesiology plan. Table 4 highlights many of the unique maternal CVD states. However, the heterogeneity contained within should underscore the importance of an individualized approach that relies on the assessment of each patient's underlying CVD and current hemodynamic status when plans are made for pregnancy, labor, delivery, and postpartum.

FUTURE DIRECTIONS

Many questions remain unanswered about the optimal care of the cardio-obstetric patient. Research from multicenter registries from pregnancy heart teams or national and international data sets may be able to address specific intrapartum management by disease type such as timing of delivery, prophylactic inotrope use, optimal anesthesia technique, which patients benefit from the resource of ECMO on standby, and improved risk prediction for acute decompensation postpartum. The assessment of New York Heart Association functional class in pregnancy is challenging because the signs and symptoms of heart failure overlap with normal pregnancy symptoms. Research to optimize the New York Heart Association classification for pregnant patients could help in appropriate triage and treatment. Training of current and future anesthesiologists in the treatment of cardio-obstetric patients can be incorporated into residency and fellowship training, and a new cardio-obstetric fellowship pathway could be created that combines a 1-year fellowship in obstetric anesthesia and a 1-year fellowship in cardiothoracic anesthesia. Point-of-care cardiac ultrasound is now recognized as an anesthesiology residency core competency, so faculty training residents and all future graduating anesthesiologists will soon have this skill for periobstetric care.

CONCLUSIONS

The American Heart Association is committed to improving maternal care before, during, and after delivery. The leading cause of maternal morbidity and mortality is CVD.[1,88] Anesthesiologists are an integral part of the pregnancy heart team because they not only provide improved recognition of patients at high cardiovascular risk but also contribute to the formulation and delivery of safe peripartum care. Standardization of the anesthetic care for pregnant women with high-risk CVD is essential as we aim to reduce and respond effectively to adverse maternal cardiovascular, fetal, and obstetric events.

ARTICLE INFORMATION

The American Heart Association makes every effort to avoid any actual or potential conflicts of interest that may arise as a result of an outside relationship or a personal, professional, or business interest of a member of the writing panel. Specifically, all members of the writing group are required to complete and submit a Disclosure Questionnaire showing all such relationships that might be perceived as real or potential conflicts of interest.

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