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Team-Based Care of Women With Cardiovascular Disease From Pre-Conception Through Pregnancy and Postpartum

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Abstract

The specialty of cardio-obstetrics has emerged in response to the rising rates of maternal morbidity and mortality related to cardiovascular disease (CVD) during pregnancy. Women of childbearing age with or at risk for CVD should receive appropriate counseling regarding maternal and fetal risks of pregnancy, medical optimization, and contraception advice. A multidisciplinary cardio-obstetrics team should ensure appropriate monitoring during pregnancy, plan for labor and delivery, and ensure close follow-up during the postpartum period when CVD complications remain common. The hemodynamic changes throughout pregnancy and during labor and delivery should be considered with respect to the individual cardiac disease of the patient. The fourth trimester refers to the 12 weeks after delivery and is a key time to address contraception, mental health, cardiovascular risk factors, and identify any potential postpartum complications. Women with adverse pregnancy outcomes are at increased risk of long-term CVD and should receive appropriate education and longitudinal follow-up.

Keywords

cardio-obstetrics; cardiovascular disease; pregnancy; team care; women

Maternal morbidity and mortality in the United States has been rising over the past several decades (1). Cardiovascular disease (CVD) is now the leading cause of pregnancy-related deaths, and many of these are preventable (2). There are a number of explanations for these trends: women are now older, have more cardiovascular risk factors, and have more complex cardiac disease at the time of their first birth (3). In response to this, calls for cardio-obstetric models of care and improved competencies have emerged (4–7). A recent American Heart Association Scientific Statement on cardiovascular considerations in caring for pregnant patients highlighted several important aspects of cardio-obstetrics care (8). In this issue of the *Journal*, on behalf of the American College of Cardiology CVD in Women Committee and the Cardio-Obstetrics Work Group, we present a 5-part Focus Seminar that addresses a wide breadth of topics in this emerging field. This document, “Cardio-Obstetrics Part 1: Team-Based Care,” describes the risk stratification of pregnant women with cardiac disease, the team-based model of cardio-obstetrics, the hemodynamic changes of labor and delivery, postpartum monitoring, and the short- and long-term complications after delivery (Central Illustration).

RISK STRATIFICATION

Pregnancy is associated with significant hemodynamic changes (Figure 1) that may be poorly tolerated by women with underlying CVD (3). Heart failure (HF) and arrhythmias are the most common complications among women with pre-existing CVD (9). Women may also present during pregnancy with previously undiagnosed CVD or develop new CVD during pregnancy, such as peripartum cardiomyopathy (PPCM). The risk of cardiovascular complications during pregnancy is variable, comparable to the general population for some women with CVD but prohibitively high risk for others such that pregnancy is not recommended. Several risk stratification tools are available to guide pregnancy planning, including the CARPREG II (Cardiac Disease in Pregnancy Study), ZAHARA

(Zwangerschap bij Aangeboren HARTAfwijking [Pregnancy in Women With Congenital Heart Disease]), and modified World Health Organization classification methods (Tables 1, 2, and 3) (9–11). Although no tool is perfect, they are good starting points and can be combined with lesion-specific data and patient-specific information to refine risk assessment. Estimates of pregnancy risks are useful for preconception counseling, determining the frequency of monitoring during pregnancy, and guiding the level of care needed during delivery and postpartum. Additionally, women with CVD may deliver preterm or have low-birth-weight babies, and these fetal and neonatal risks should be discussed, as well as potential inheritability of certain conditions.

For women at excessive risk of severe morbidity or mortality, other options such as adoption or gestational carriers can be explored. Women may also be encouraged to consider how they would feel about the need to terminate a pregnancy at a pre-viable gestational age should the woman become unable to tolerate the hemodynamic changes of early to mid-pregnancy, though most women become symptomatic later in pregnancy. Given the complexities of these difficult choices, conversations should occur before conception with awareness of local laws that may limit access to these medically indicated procedures.

CARDIO-OBSTETRICS TEAM

Multidisciplinary collaboration is key to successful management of women with CVD pursuing pregnancy, and coordinated cardio-obstetrics clinics have been shown to decrease adverse cardiac complications during pregnancy (9). Women with CVD should ideally be evaluated before conception for discussions about pregnancy risks, optimization of their cardiovascular health, substitutions of teratogenic medications, and education about the need for regular surveillance through pregnancy and postpartum. Members of the cardio-obstetrics team will vary based on the complexity of the patient's cardiac condition, but those with intermediate- and high-risk conditions should be cared for by a multidisciplinary team experienced in the management of cardiac disease in pregnancy (Table 4) (3,6). For patients without CVD, but with cardiovascular risk factors including chronic or gestational hypertensive disorders or other adverse pregnancy outcomes (APOs), multidisciplinary collaboration may be important for reducing short- and long-term cardiovascular complications related to pregnancy.

Pre-pregnancy counseling and close monitoring throughout gestation is needed for optimal outcomes. From an operational standpoint, regular multidisciplinary team meetings are essential to facilitate patient-centered decisions about testing, disease management, and coordinated delivery plans. Contraception should also be discussed with patients before delivery to facilitate tubal ligation or long-acting reversible contraception (intrauterine devices or progesterone implants) at delivery when desired and feasible.

TIMING OF DELIVERY

A detailed, individualized delivery plan should be created by the cardio-obstetrics team through shared decision-making with the patient. Delivery plans should be created early, usually between 20 and 28 weeks of gestation, and recorded in the medical record. The plan

should be easily accessible to all health care professionals involved with the woman's care. This document should include recommendations regarding the location, timing, and mode of delivery, intrapartum monitoring, management of complications and necessary resources, and a plan for postpartum surveillance (3). Some women at high risk for postpartum complications may benefit from monitoring in a coronary care unit postpartum.

In the absence of spontaneous onset of labor or indicated delivery before term, scheduled induction of labor for pregnant women with stable cardiac disease may be considered at 39 weeks of gestation with Cesarean delivery usually reserved for obstetric indications (12,13). Earlier delivery may be indicated for women with certain high-risk conditions with serious cardiac complications or hemodynamic instability. Pregnant women with CVD should deliver at a hospital with the appropriate maternal and neonatal level of care for the degree of risk (14). The resources needed to minimize maternal and fetal complications should be anticipated, outlined and documented before delivery and included in the delivery plan. It is preferable to have women with moderate and severely complex heart disease deliver in tertiary or quaternary centers where care is provided under the guidance of the multidisciplinary cardio-obstetrics team (3,14).

FETAL COMPLICATIONS OF PREMATURE DELIVERY

If the maternal condition deteriorates or if a woman presents with new serious cardiac disease, the cardio-obstetrics team may need to discuss the need for a premature delivery with the patient. Input should be obtained from maternal fetal medicine and/or neonatology regarding the likely outcome for the neonate, which will depend on gestational age, fetal growth, and the presence or absence of structural or genetic anomalies. At extremely low gestational ages (22 0/7 to 24 6/7 weeks), the National Institute of Child and Human Development (NICHD) Extremely Preterm Birth Outcomes Tool can be used to help guide counseling and recommendations. Morbidity and mortality estimates for later gestational ages are presented in Table 5 (15). Although care should be taken to not recommend premature delivery without consideration of neonatal risks, deterioration of maternal status may jeopardize both the maternal and fetal lives.

CARDIOVASCULAR HEMODYNAMICS OF LABOR AND DELIVERY

Many variables influence the hemodynamic state of a woman during delivery (Figure 2). Although it may not be possible to precisely predict the effects of various birth events or interventions, there are central themes to the hemodynamic patterns of vaginal and Cesarean birth. Additionally, medications commonly used during labor and delivery may need to be modified for women with CVD—while keeping in mind that maternal hemorrhage is a life-threatening condition that is also poorly tolerated by women with significant underlying CVD (Table 6).

VAGINAL DELIVERY.

Labor and the associated uterine contractions, pain, and anxiety result in increases in heart rate, systolic blood pressure, and cardiac output, which become greater as women progress through the first stage of labor. Effective neuraxial labor analgesia reduces labor pain and

thereby mitigates these hemodynamic effects; however, increases in cardiac output with contractions can occur even with effective analgesia (16,17). Immediately after epidural or spinal anesthesia, post-analgesia hypotension may occur due to vasodilatory effects of the local anesthetic or the sudden elimination of labor pain resulting in a drop in plasma catecholamines.

The greatest hemodynamic changes of vaginal birth occur during the second stage of labor, when the patient is pushing to deliver the infant, and during delivery. Although vaginal delivery involves repeated performance of the Valsalva maneuver, which can result in transient reductions in preload, afterload, and cardiac output, with a compensatory increase in cardiac output with the release of Valsalva (16,18,19), a large study demonstrated that Valsalva in the second stage of labor was not associated with significant hemodynamic changes or adverse outcomes, supporting the notion that Valsalva should be liberalized during the second stage of labor (12). Additional important hemodynamic changes can happen at birth when increases in heart rate, stroke volume, and cardiac output occur due to sudden decompression of the inferior vena cava and autotransfusion from the contracting evacuated uterus (20,21).

CESAREAN DELIVERY.

Unlike with vaginal delivery, complete insensitivity to surgical stimulation is needed for Cesarean delivery. Neuraxial analgesia is preferred over general anesthesia because it allows the patient to experience childbirth while avoiding airway manipulation and the tocolytic effect of, and unwanted fetal exposure to, volatile anesthetics. Neuraxial anesthesia may be contraindicated if a patient received recent antithrombotic therapy because of the risk of spinal epidural hematoma (22). The hemodynamic effects of neuraxial analgesia are more pronounced for Cesarean delivery than labor analgesia because the nerve block must be higher and more dense. Neuraxial analgesia causes a sympathectomy, resulting in a decrease in systemic vascular resistance, increase in heart rate, and decrease in mean arterial pressure; therefore, vasoactive medications such as phenylephrine or norepinephrine are typically administered during block onset. Although spinal anesthesia provides a denser and more reliable block, it causes more rapid sympathectomy than a slowly titrated epidural block. For patients with preload dependent conditions, an alternative option is a sequential combined spinal epidural—a small amount of local anesthetic placed in the intrathecal space followed by slowly dosing the epidural catheter (23). Given the significant hemodynamic effects of various medications, an experienced anesthesiologist is an essential member of the cardio-obstetrics team.

CARDIOVASCULAR MONITORING FOR LABOR AND DELIVERY

Laboring women with significant cardiac disease should have a pulse oximeter to monitor for maternal bradycardia, tachycardia, or hypoxemia. Telemetry should be used for women at risk of hemodynamically significant arrhythmias (ventricular tachycardia or sustained supraventricular tachycardia). Arterial lines are typically only needed when hypotension or hypertension requires immediate recognition and treatment (e.g., severe aortic stenosis, severe mitral stenosis, or pulmonary arterial hypertension during Cesarean delivery). Central

venous access is rarely used during delivery, but may be considered for women with severe HF who are likely to require inotropic or vasopressor support.

MODE OF DELIVERY IN WOMEN WITH CARDIOVASCULAR DISEASE

Vaginal delivery with adequate analgesia is associated with fewer maternal complications and is the preferred mode of delivery with few exceptions (3). Cesarean delivery is recommended for women with Marfan syndrome with dilated aorta >45 mm and some other high-risk aortopathies, women with a history of acute or chronic aortic dissection, women who receive therapeutic anticoagulation with vitamin K antagonists, which place the fetus at risk for intracranial hemorrhage at the time of vaginal delivery, women with severe pulmonary arterial hypertension, and women in acute decompensated HF in whom urgent delivery is warranted (24). Cesarean delivery should also be considered for severe aortic and mitral stenosis. Otherwise, vaginal delivery is preferred and is associated with shortened hospital stay and reduced risk of sudden death, peripartum infections, and hemorrhage (13,25). Advanced planning of the timing and mode of delivery are vital responsibilities of the cardio-obstetrics team. Understanding the hemodynamic changes and physiology of labor and delivery, and its impact on the specific condition of the mother helps facilitate this decision.

POSTPARTUM MONITORING

Appropriate postpartum monitoring is important for all women, but it is critically important in women with high risk CVD. Postpartum recovery in a cardiac care unit versus postpartum obstetric care unit should be individualized depending on clinical status of the patient, risk for cardiac complications, and comfort level within each care team. Women at high risk for hemodynamically significant arrhythmias should be on telemetry. In most cases, cardiovascular imaging is not indicated in the immediate postpartum period. Planned postpartum length of stay varies depending on the specific cardiovascular condition, but women at highest risk for postpartum complications should be monitored for ≥ 72 h. Hemodynamic changes in the postpartum period may pose significant risk to women with HF, pulmonary arterial hypertension, or valvular disease, thus warranting extended postpartum monitoring.

For safe discharge of both mother and infant, it is imperative to have a discharge plan in place. Just as the cardio-obstetrics team promotes maternal care in the antepartum/intrapartum period, establishing an interdisciplinary plan to assess all women in the subsequent weeks after discharge (via obstetrics, maternal fetal medicine, cardiology and/or primary care) is critical in ensuring maternal safety. Many cardiovascular complications, including preeclampsia, PPCM, pulmonary embolism, and aortic or spontaneous coronary artery dissection can occur postpartum. Patients must be made aware of the need to self-monitor and to alert their medical team if they experience “red flag” symptoms (Figure 3). Early post-discharge blood pressure measurement within 3 days is imperative for women with and at risk for hypertensive complications. The American College of Obstetricians and Gynecologists (ACOG) guidelines support an initial postpartum assessment within the first 3

weeks postpartum with interim follow-up as needed and a comprehensive visit no later than 12 weeks after birth (26).

The postpartum period is also an important time to address breastfeeding, family planning and contraception, mental health, and the need for long-term cardiovascular follow-up if not previously reviewed. Most cardiovascular medications may be continued during lactation (27).

POSTPARTUM COMPLICATIONS

Cardiovascular complications are frequently encountered in the first days to months postpartum. In women with CVD, readmissions in the first 42 days postpartum are most commonly due to HF, arrhythmias, hypertensive syndromes, and pregnancy complications such as hemorrhage and infection (28) (Figure 4). Women at highest risk for readmission include those with older age, obesity, cardiomyopathy, pulmonary hypertension, pre-eclampsia/eclampsia during pregnancy, postpartum hemorrhage, and Medicaid/Medicare insurance (28).

HEART FAILURE.

Pregnancy-related HF may be due to systolic dysfunction related to PPCM (29,30), diastolic dysfunction (31,32) or pre-existing heart disease (9,33). PPCM is most commonly diagnosed in the first month after delivery, whereas women with structural heart disease frequently develop symptomatic HF in the third trimester or early postpartum period (9,29,33). Among all pregnancy-related HF admissions, 60% occur postpartum (34), and cardiomyopathy is a leading cause of maternal mortality (35,36). In women with PPCM, worsening of left ventricular systolic function is reported in about 20% of women undergoing a subsequent pregnancy who have normalization of systolic function after their index pregnancy compared with about one-half of women who have not had full recovery in left ventricular function (29). Physiological changes associated with pregnancy gradually return to baseline in the first few weeks postpartum. The diagnosis of HF is frequently delayed; therefore, clinicians should maintain a high index of suspicion with any signs or symptoms consistent with a HF diagnosis such as shortness of breath, edema, or cough. A low threshold for echocardiography and measurement of biomarkers is important to make a prompt diagnosis. Women who have been on guideline-directed medical therapy for HF during pregnancy should have this readjusted and optimized postpartum based on clinical and lactation status.

ARRHYTHMIAS.

Arrhythmias are the second most common cardiac indication for readmission postpartum in women with known CVD (28). A National Inpatient Sample analysis of arrhythmia burden found atrial fibrillation was the most common arrhythmia, but did not address timing across the pregnancy continuum (37). Women with long QT syndrome, especially LQT2 genotype are at increased risk of arrhythmia during the 9 months postpartum. Treatment with beta-blockers, especially nadolol, is associated with a reduction in adverse events (38,39).

Maternal cardiac arrest is infrequent, estimated at approximately 1:12,000 admissions for delivery. The most common etiologies are maternal hemorrhage and amniotic fluid

embolism. However, venous thromboembolism and acute coronary syndromes, including spontaneous coronary artery dissection, are other important etiologies (40–42). Maternal cardiac arrest occurring before delivery requires management modifications based on gestational age such as performance of lateral uterine displacement and rapid decision for perimortem Cesarean delivery. Postpartum management need not be modified although calcium should be given if magnesium has been administered for postpartum pre-eclampsia (40).

POSTPARTUM HYPERTENSION AND PRE-ECLAMPSIA.

Pre-eclampsia is reported in approximately 2% to 8% of pregnancies, and contrary to the traditional teaching that delivery of the placenta cures the disease, it is now recognized that pre-eclampsia can develop de novo postpartum. Postpartum hypertension may also be secondary to persistence of gestational hypertension or chronic hypertension. Current ACOG recommendations include a blood pressure check for women with any hypertensive disorder of pregnancy no later than 7 to 10 days postpartum and within 72 h for those with severe hypertension (systolic blood pressure ≥ 160 mm Hg systolic or ≥ 110 mm Hg diastolic). Severe hypertension in a pregnant or a recently postpartum woman is a medical emergency that requires prompt treatment to reduce risk of maternal stroke and other complications (43). New-onset severe range hypertension with or without other organ involvement requires urgent therapy with magnesium sulfate and antihypertensive medications, and may necessitate early delivery (Figure 5). New-onset tonic-clonic seizures suggest eclampsia, which also requires emergent magnesium sulfate in addition to blood pressure control. The presentation of hemolysis, elevated liver enzymes, and low platelet count (HELLP syndrome) represents a severe form of pre-eclampsia (43). Acute cardiac complications of pre-eclampsia include diastolic dysfunction and pulmonary edema (32). Moreover, pre-eclampsia is a known risk factor for PPCM (29). Hypertension associated with symptoms of HF, palpitations, or shortness of breath should prompt urgent evaluation for cardiomyopathy. Stroke in pregnancy and postpartum is also strongly associated with hypertension (44).

HEMORRHAGE AND ANTICOAGULATION.

Postpartum hemorrhage is defined as $>1,000$ ml of blood loss in the first 24 h after delivery associated with signs or symptoms of hypovolemia (45). Primary hemorrhage occurs within the first 24 h postpartum and is most commonly secondary to uterine atony. Hemorrhage occurring from 24 h to 6 to 12 weeks is categorized as secondary and is most commonly due to uterine atony, lacerations, retained products of conception, infection, subinvolution of the placental site, and inherited coagulation defects (45). Risk factors for hemorrhage include pre-eclampsia, anticoagulation therapy, forceps delivery, emergency caesarean delivery, and general anesthesia. In a study of women with congenital heart disease, higher CARPREG risk scores were associated with increased risk of hemorrhage, and this was greatest in women with Fontan circulation (46). For patients who would hemodynamically decompensate with hypotension or a drop in preload, hemorrhage should be recognized and treated rapidly.

Uterine atony is treated with uterotonic medications, which include oxytocin, misoprostol, carboprost, and methylergonovine. The hemodynamic consequences of several obstetric

drugs are reviewed in Table 6. Carboprost (prostaglandin F2 alpha) causes an increase in pulmonary vascular resistance and is contraindicated in patients with pulmonary hypertension or right ventricular failure. Methylergonovine has been associated with an elevation in systemic vascular resistance and vascular spasm and is contraindicated in hypertensive disorders of pregnancy and CVD. Although oxytocin causes a decrease in systemic vascular resistance, if diluted and carefully titrated, it can be safely administered. Misoprostol has few hemodynamic side effects. Hemorrhage should be treated promptly and aggressively, using the safest possible medications for the patient's cardiovascular condition but also weighing the risks of ongoing hemorrhage on the cardiovascular system.

THE FOURTH TRIMESTER

The fourth trimester is the period following delivery through the first 12 weeks postpartum (26). This is a vital period for follow-up, given that over 70% of maternal deaths occur postpartum, and nearly 40% occur within the first 6 weeks (36). Age >30 years, Hispanic or non-Hispanic Black race/ethnicity, and women with multiple gestation pregnancies have an increased likelihood of not receiving postpartum care in the first 6 months (47). Approximately 40% of women do not attend postpartum visits, citing stress, fatigue, inconvenience, adjustments to caring for a newborn, lack of social support, finances, transportation, or language as major barriers (26,47,48).

Telemedicine has the potential for improving postpartum care by reducing some of the barriers to care such as transportation and language barriers, though if not implemented appropriately may increase disparities. Web-based education modules could also improve patient education. Telehealth and internet-based interventions in pregnant women have been shown to be effective in treatment of hypertensive disorders of pregnancy pre- and postpartum, tobacco cessation, postpartum depression, and postpartum weight management (49).

Care during the fourth trimester should focus on screening and early intervention, particularly for women at increased risk of CVD, metabolic syndrome, chronic kidney disease, and diabetes mellitus (50). At postpartum visits, clinicians should assess, counsel, and treat women about multiple facets of cardiovascular health (Figure 6). Education, risk factor modification, and contraception should be addressed. Short birth intervals of <12 to 18 months or conception within 6 months of prior birth carry increased risk for APOs, including low birth weight, and family planning should be discussed if not previously addressed (51).

PREGNANCY COMPLICATIONS AND LONG-TERM CARDIOVASCULAR CARE

The association between APOs and long-term CVD risk has become increasingly recognized. Conditions such as hypertensive disorders of pregnancy, gestational diabetes, preterm birth, and small for gestational age are associated, not only with short-term maternal and fetal morbidity and mortality, but also with long-term risk of cardiovascular events such as myocardial infarction, stroke, and HF (Figure 7) (52–58). Recent data suggest that

hypertensive disorders of pregnancy are also associated with a broader range of CVD, including aortic stenosis and mitral regurgitation (59). Women with a history of APOs have a greater burden of CVD risk factors (60–62); however, the future cardiovascular risk associated with APOs is independent of traditional risk factors (63). Whether the association between APOs and future CVD are related to an underlying predisposition or secondary to vascular insults that occur at the time of pregnancy remains to be elucidated. The causes are likely multifactorial and related to a combination of inflammation, vascular dysfunction, and accelerated development of traditional CVD risk factors (64). Given the approximately 2- to 4-fold increased risk of composite CVD associated with APOs (Figure 7), obtaining a detailed pregnancy history is a vital component of a comprehensive cardiovascular risk assessment in all women. ACOG recommends cardiovascular assessment beyond the fourth trimester for women with a history of any APO, including body mass index, lipids, blood pressure, and glucose measurements at 3 months postpartum and repeat assessment at 6 to 12 months postpartum after implementation of appropriate lifestyle interventions if abnormalities are identified on initial evaluation (3). Because many of these pregnancy complications occur in young women who may not routinely seek preventative care, it is important to raise awareness about the associated CVD risk among patients and clinicians across multiple specialties including internal medicine, family medicine, cardiology, endocrinology, and obstetrics/gynecology. Implementation of prevention strategies including education, screening, and aggressive risk factor modification throughout the life course of a woman with an APO history may result in improvement in long-term CVD outcomes in this population (65).

DISPARITIES IN CARE

Substantial racial and ethnic disparities in maternal morbidity and mortality exist in the United States. Multiple social determinants of health, including black race, Hispanic ethnicity, lack of insurance, lower education levels, food and housing insecurity, crime, and systemic racism are associated with higher maternal morbidity and mortality (66–68). Women in rural communities also have higher rates of pre-pregnancy hypertension and worse maternal outcomes, while facing declining access to obstetric services (69,70). In order to improve maternal cardiovascular outcomes, attention to the social determinants of health driving these significant disparities must be an integral part of the cardio-obstetric model of care.

CONCLUSIONS

The cardio-obstetrics model of care encompasses management of women before, during, and after pregnancy. Preconception counseling involves risk assessment, medical optimization, and contraception. During pregnancy, team-based care across multiple specialties is necessary and includes serial antenatal monitoring and delivery planning, with an appreciation for the hemodynamic changes of labor and delivery. After delivery, awareness of short- and long-term postpartum complications can help reduce immediate cardiac complications and improve long-term outcomes. Patient care during the fourth trimester should address CVD risk factor management, contraception counseling, and prevention of adverse events. The following issues of this 5-part series will provide additional guidance on

the cardio-obstetrics management of specific CVD states, as well as contraception and reproductive planning.

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ABBREVIATIONS AND ACRONYMS

ACOG	American College of Obstetricians and Gynecologists
APO	adverse pregnancy outcome
CVD	cardiovascular disease
HF	heart failure
PPCM	peripartum cardiomyopathy

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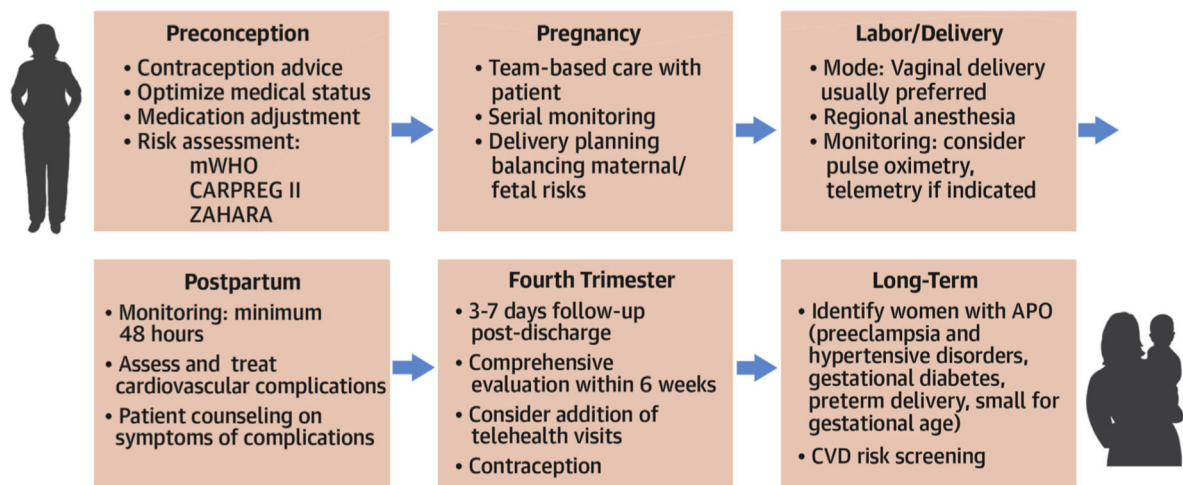
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HIGHLIGHTS

- Cardio-obstetrics involves clinicians from multiple specialties focused on pregnant patients from preconception through the postpartum period.
- Risk assessment tools can guide conversations about maternal and fetal risks in women with cardiovascular disease who are pregnant or considering pregnancy.
- The cardio-obstetrics team should anticipate potential cardiovascular complications of pregnancy, labor and delivery, and the postpartum period.
- Postpartum care is an ongoing, integral component of cardio-obstetrical patient management.



CENTRAL ILLUSTRATION. The Cardio-Obstetrics Model of Care

The cardio-obstetrics model of care involves multiple specialists working together and with the patient to address issues from preconception, through pregnancy and delivery, and the postpartum period. APO = adverse pregnancy outcomes; CARPREG II = Cardiac Disease in Pregnancy study; CVD = cardiovascular disease; mWHO = modified World Health Organization.

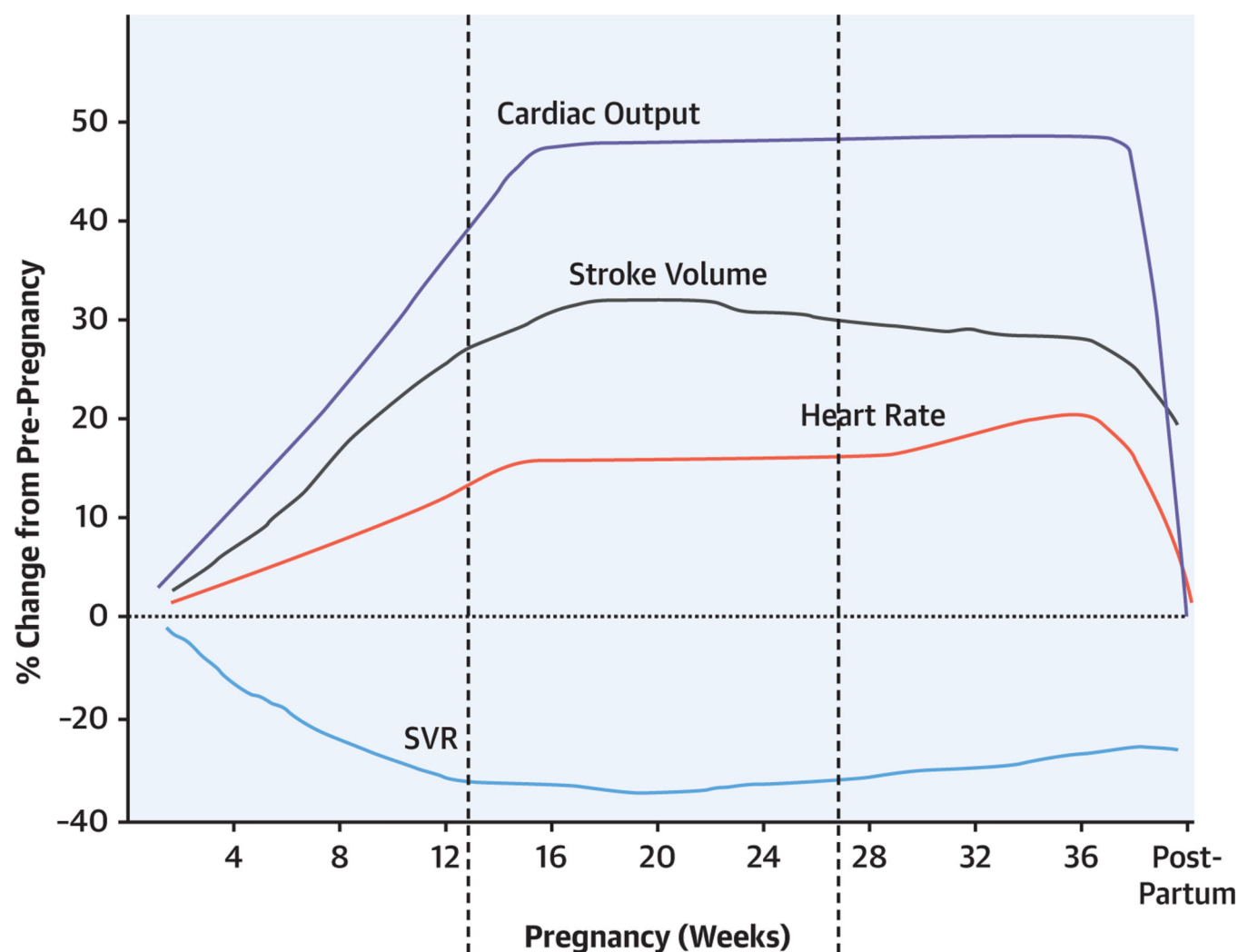


FIGURE 1. Hemodynamic Changes From Baseline During Pregnancy

Significant changes in cardiac output, heart rate, stroke volume, and systemic vascular resistance occur during pregnancy. SVR = systemic vascular resistance.

Patient	Disease	Pregnancy
• Intravascular Volume Status • Blood Pressure • Heart Rate • Body Position • Style of Pushing • Parity	• Lesion Type • Lesion Severity • Ventricular Function • Comorbidities	• Gestational Age • Fetal Size • Anesthesia Type • Anesthesia Efficacy • Mode of Delivery • Obstetric Medication Administration • Blood Loss

FIGURE 2. Factors Influencing Delivery Hemodynamics

Several factors related to the patient, cardiovascular disease, and pregnancy status will influence the hemodynamic changes during delivery.

Peripartum Red Flag Signs and Symptoms

Chest Pain	Tachycardia
Dyspnea	Non-Vagal Syncope
Orthopnea	Headache
Cough	Visual Changes
Edema	Hypotension/Hypertension

FIGURE 3. Signs and Symptoms Concerning for Cardiovascular Complications During or After Pregnancy

Patients and clinicians need to be aware of signs and symptoms that may signal cardiovascular complications during and after pregnancy.

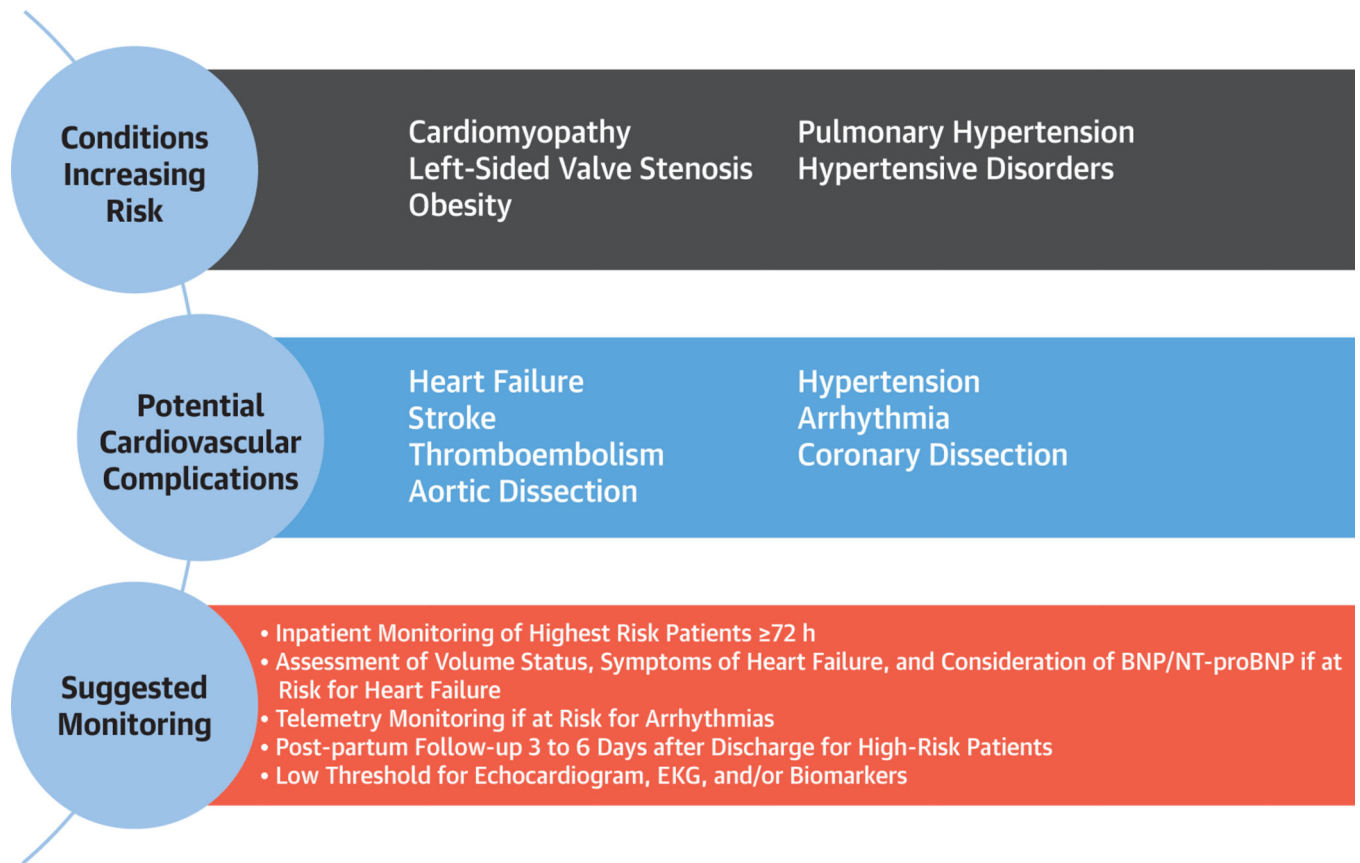


FIGURE 4. Postpartum Complications in Women with Cardiovascular Disease

Postpartum complications are more likely with certain cardiovascular conditions and additional postpartum monitoring may be needed. BNP = B-type natriuretic peptide; EKG = electrocardiogram; NT-proBNP = N-terminal pro-B-type natriuretic peptide.

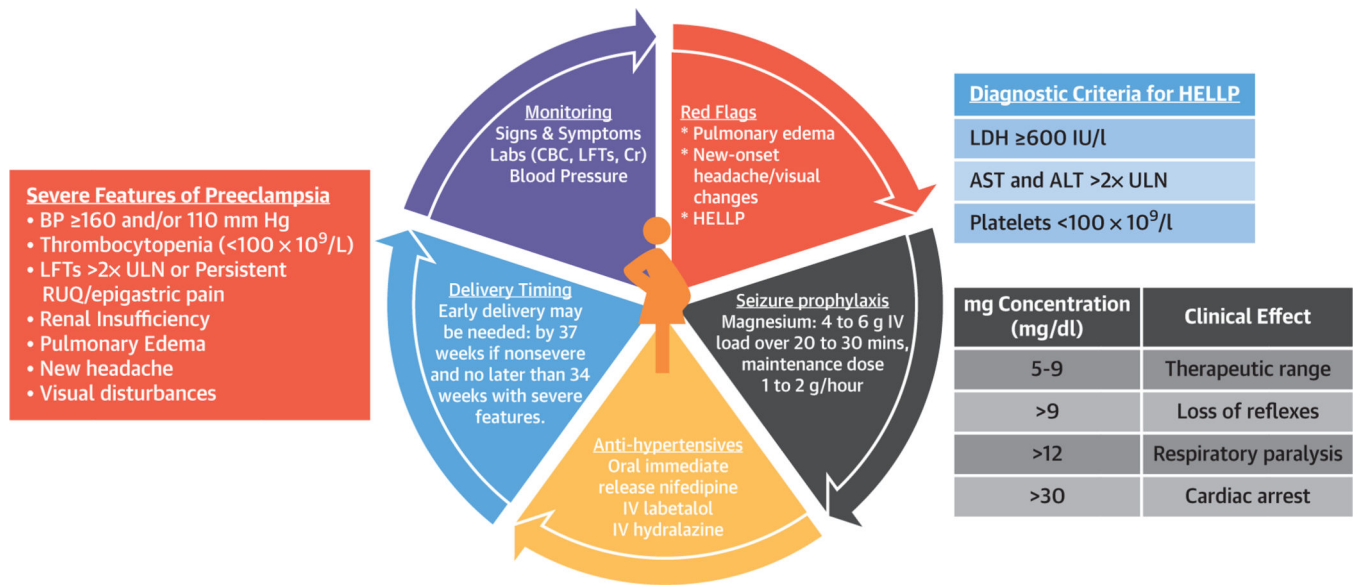


FIGURE 5. Management of Severe Hypertension/Pre-Eclampsia During Pregnancy and in the Early Postpartum Period

Severe hypertension/pre-eclampsia is a medical emergency and requires prompt recognition and treatment. If this occurs during pregnancy, early delivery may be indicated. ALT = alanine aminotransferase; AST= aspartate aminotransferase; BP = blood pressure; CBC = complete blood count; Cr = creatinine; HELLP = hemolysis, elevated liver enzymes, low platelet count; IV = intravenous; LDH = lactate dehydrogenase; LFT = liver function test; RUQ = right upper quadrant; ULN = upper limits of normal.



FIGURE 6. The Fourth Trimester: From Delivery to 12 Weeks Postpartum

Clinicians should ACT during each postpartum visit: Assess, Counsel, and Treat. The fourth trimester includes the first 12 weeks after delivery and serves as an important time period for assessment, counseling, and treatment to reduce the long-term risk of cardiovascular disease. APO = adverse pregnancy outcome; CVD = cardiovascular disease; DM = diabetes mellitus; HF = heart failure; IHD = ischemic heart disease; OR = odds ratio.

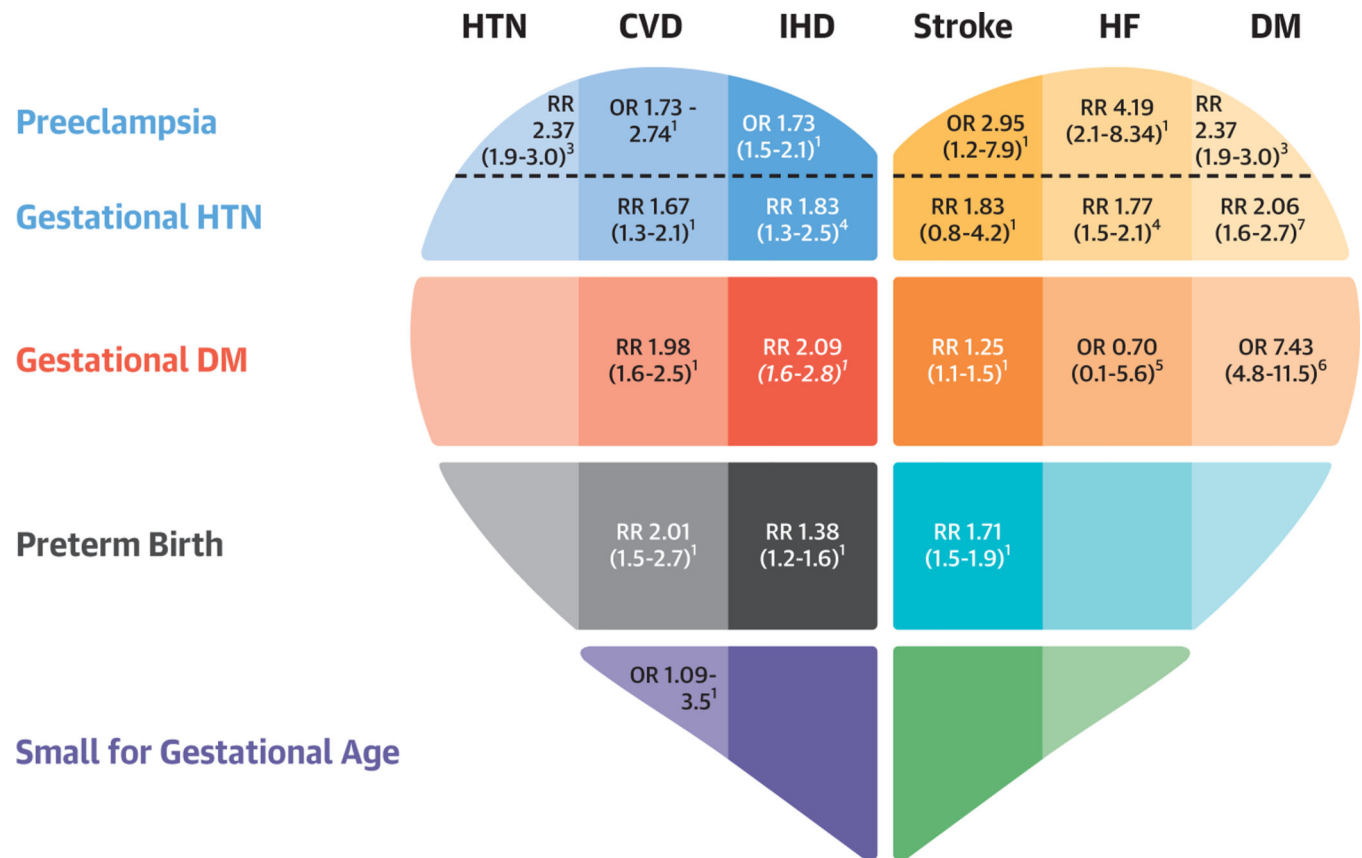


FIGURE 7. APOs and Future Cardiovascular Risk

Displayed are the pooled risks of future CVD and CVD risk factor development from systematic reviews of APOs including hypertensive disorders of pregnancy (pre-eclampsia and gestational hypertension), gestational DM, preterm birth, and small for gestational age.

Blank spaces indicate the data have not been synthesized in a published systematic review.

APO = adverse pregnancy outcome; CVD = cardiovascular disease composite; DM = diabetes mellitus; HF = heart failure; HTN = hypertension; IHD = ischemic heart disease; OR = odds ratio; RR = relative risk.

TABLE 1**CARPREG II Risk Prediction Model**

CARPREG II Predictors	Points
Prior cardiac event or arrhythmia	3
Baseline NYHA functional class III to IV or cyanosis	3
Mechanical valve	3
Ventricular dysfunction	2
High-risk left-sided valve disease/LVOT obstruction	2
Pulmonary hypertension	2
Coronary artery disease	2
High-risk aortopathy	2
No prior cardiac intervention	1
Late pregnancy assessment	1
CARPREG II Score	Predicted Risk, %
0 to 1	5
2	10
3	15
4	22
>4	41

CARPREG = Cardiac Disease in Pregnancy Study; LVOT = left ventricular outflow tract; NYHA = New York Heart Association.

TABLE 2**ZAHARA Risk Prediction Model Derived From Patients With Congenital Heart Disease**

ZAHARA Predictors	Points
Prior arrhythmia	1.5
Cardiac medications before pregnancy	1.5
NYHA functional class $\geq$ II	0.75
Left heart obstruction	2.5
Moderate or severe mitral regurgitation	0.75
Moderate or severe tricuspid regurgitation	0.75
Mechanical valve	4.25
Cyanotic heart disease (corrected or uncorrected)	1
ZAHARA Score	Predicted Risk, %
0–0.5	2.9
0.51–1.50	7.5
1.51–2.50	17.5
2.51–3.50	43.1
>3.50	70.0

NYHA = New York Heart Association; ZAHARA = Zwangerschap bij Aangeboren

HARtAfwijking (Pregnancy in Women With Congenital Heart Disease) study.

TABLE 3

Modified WHO Risk Stratification Model

Modified WHO Class	Conditions	Predicted Risk, %
I—No higher risk than the general population	Uncomplicated, small or mild lesions including pulmonary stenosis, VSD, PDA, and mitral valve prolapse with no more than trivial mitral regurgitation Successfully repaired simple lesions including ostium secundum ASD, VSD, PDA, and TAPVD Isolated PVCs and PACs	2.5–5
II—Small increased risk of maternal morbidity and mortality	Unoperated ASD Repaired tetralogy of Fallot Most arrhythmias Coarctation of the aorta without significant gradient or aneurysm (repaired or unrepaired) Long QT syndrome	5.7–10.5
II to III	Mild LV impairment Hypertrophic cardiomyopathy Marfan syndrome without aortic dilation Heart transplant Native or tissue valve disease not considered WHO class IV Bicuspid aortic valve without aortic dilatation	10–19
III—Significant risk of maternal morbidity and mortality	Mechanical valve Systemic RV Post-Fontan operation Cyanotic heart disease Other complex congenital heart repair Aortic dilation without known fibrinogen disease Coarctation of the aorta with residual gradient or aneurysm (repaired or unrepaired) Marfan syndrome with aortic root dilation <45 mm or following aortic replacement Bicuspid aortic valve with aortic root dilation 45 to 50 mm	19–27
IV—Pregnancy contraindicated	Pulmonary arterial hypertension of any cause Severe left ventricular dysfunction (LVEF <30% or NYHA functional class III to IV) Previous peripartum cardiomyopathy with any residual impairment of LV function Severe left heart obstruction (AVA <1 cm ² or peak gradient >50 mm Hg; MVA <1.5 cm ²) Marfan syndrome with aortic dilation >45 mm Bicuspid aortic valve with aortic dilation >50 mm	40–100

ASD = atrial septal defect; AVA = aortic valve area; LV = left ventricular; LVEF = left ventricular ejection fraction; MVA = mitral valve area; NYHA = New York Heart Association; PAC = premature atrial contraction; PDA = patent ductus arteriosus; PVC = premature ventricular contraction; RV = right ventricle; TAPVD = total anomalous pulmonary venous drainage; WHO = World Health Organization.

TABLE 4

Cardio-Obstetrics Teams

Modified WHO Class	Essential Team Members	Potential Team Members
1	Obstetrician	ACHD specialist
	Primary care physician	Advanced practice practitioner
	Cardiology consultation	Geneticist
	Nurses: outpatient, labor and delivery	Other specialists
II	Obstetrician	ACHD specialist
	Primary care physician	Advanced practice practitioner
	Maternal fetal medicine	Geneticist
	Cardiology consultation	Neonatologist
	Nurses: outpatient, labor and delivery	Social worker
III to IV		Other specialists
	Obstetrician	ACHD cardio-obstetrics specialist
	Primary care physician	Pharmacist
	Maternal fetal medicine	Cardiac anesthesiologist
	Cardio-obstetrics expert	Aortopathy specialist
	Obstetric anesthesiologist	Electrophysiologist
	Nurses: outpatient, labor and delivery	Advanced heart failure cardiologist
		Pulmonary hypertension specialist
		Interventional cardiologist
		Cardiac surgeon
		Intensive care team
		Neonatologist
		Geneticist
		Hematologist
		Mental health specialist
		Social worker
		Case manager
		Advanced practice practitioner

ACHD = adult congenital heart disease; WHO = World Health Organization.

TABLE 5

Neonatal Mortality Estimates Based on Premature Gestational Age

Gestational Age at Delivery Weeks	Neonatal Death Rate/100 Live Births	Neonatal Death or Severe Morbidity Rate/ 100 Live Births
24–27	14.2	71.7
28–31	3.0	36.6
32–33	1.0	16.3
34–36	0.5	5.4
All (24–36)	1.3	11.9

Based on a population-based study of all singleton births from the state of Washington from 2011 to 2012. Severe morbidity included bronchopulmonary dysplasia, intraventricular hemorrhage ≥ 3 , periventricular leukomalacia, retinopathy of prematurity, necrotizing enterocolitis, neonatal sepsis, convulsions of newborn, and severe birth trauma. Data are from Richter et al. (15).

TABLE 6

Obstetric Medications and Considerations for Women With High-Risk CVD

Medication	Indication	Side Effects	Considerations
Oxytocin (Pitocin)	Labor augmentation Prevention of postpartum hemorrhage	Hypotension Decrease in peripheral vascular resistance Large bolus can cause sudden decrease afterload and reflex tachycardia Rare reports of ischemia	Avoid bolus in complex CVD when possible Consider use as a dilute solution in a continuous IV infusion
Terbutaline	Stop premature labor; prolonged or frequent uterine contractions	Hypertension and tachycardia (1% to 10%)	Extreme caution, contraindicated
Methylergonovine (Methergine)	Stop postpartum hemorrhage	Vasoconstriction leading to hypertension and myocardial ischemia	Avoid if possible with chronic hypertension, pre-eclampsia, aortopathies, ischemic heart disease
Carboprost tromethamine (Hemabate)	Prostaglandin used for refractory postpartum uterine bleeding or pregnancy termination	Hypertension	Avoid in women with vascular disease or aortic aneurysms; pulmonary hypertension; significant shunt lesions

CVD = cardiovascular disease; IV = intravenous.