The Cardiovascular Complications of Pregnancy

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During the course of a normal pregnancy, the cardiovascular system of the mother is required to adapt to significant alterations in hemodynamics, including an almost 50% increase in cardiac output. This change in cardiac output is mediated by a significant increase in heart rate, a change in blood volume, as well as a neurohormonally mediated increase in vasodilatation. Simultaneously, significant changes occur in other organ systems, which also affect the cardiovascular system. For instance, there are increases in erythropoiesis to increase red cell mass, increased production of procoagulant factors, and profound activation of the collagenolytic system. To discuss the multitude of cardiovascular complications that can occur during pregnancy, we must understand the adaptations required in the cardiac, hematologic, and musculoskeletal systems. The purpose of this review is to delineate the adaptations required by each organ system and to review the complications that result when maternal physiology is unable to make the required adaptations.

Cardiovascular System

The first change in the cardiovascular system initiated by pregnancy may be a decrease in systemic vascular resistance, since recent studies have demonstrated that increases in glomerular filtration rate and renal blood flow are mediated by a decrease in glomerular arteriolar resistance and precede other changes. This decrease in vascular tone is sensed by the kidney and induces compensatory mechanisms to increase plasma volume and cardiac output. The decreased systemic vascular resistance is thought to be mediated by vasoactive prostaglandins and enhanced nitric oxide (NO) production. Nitric oxide is an important vasodilator produced by the endothelium, and recent work notes an increase in NO production in pregnant mammals. This increase in NO metabolites has also been confirmed in humans, and the syncytiotrophoblast is known to be an important site of NO synthesis. Placental production of NO maintains vasodilatation of the uterine vessels and ensures a high flow/low pressure fetoplacental and uteroplacental system.

In addition to the reduced afterload created by the low-pressure uterine circulation, there is also a reduced response to vasoconstrictors such as norepinephrine and angiotensin II during pregnancy. The mechanism by which this reduced responsiveness occurs is not well understood but does not appear to be mediated by estrogen or progesterone. This overall vasodilatory effect leads to a decrease in mean arterial blood pressure and activates the renin-angiotensin system as well as production of vasopressin to increase plasma volume.

When measuring plasma volume by Evans blue dye dilution, Bernstein et al found that plasma volume had increased by 14% at 12 weeks of gestation. The increase in plasma volume continues until the 34th week of gestation. The expansion of blood volume is accompanied by a 7- to 8-L increase in total body fluid volume distributed between the...
fetus, amniotic fluid, and the intracellular and extracellular space. This increase in plasma volume is one factor responsible for the increase in cardiac output that occurs with normal pregnancy. A recent study that used echocardiography to assess changes in the hemodynamics of 35 healthy pregnant women found a 46% increase in cardiac output at 37 weeks gestation when compared to postpartum values with a mean cardiac output of 6.94 L/min at term. Although the mean cardiac output continued to increase throughout pregnancy until term, statistically significant changes occurred in the mid second trimester and late second trimester. The increase in cardiac output was mediated by both an increase in heart rate (15%) and an increase in stroke volume (24%).

In addition, the peripheral vascular resistance measured during this echocardiographic analysis was found to decrease by 32%. As mentioned above, the decrease in peripheral vascular resistance may be the initial and the most important adaptation to pregnancy by the cardiovascular system, since without a decrease in vascular tone, the increases in blood volume would result in profound hypertension. When this decrease in vascular tone does not occur, the mother may be at risk for disorders of hypertension during pregnancy.

**Hematologic System**

Changes in the hematologic system during pregnancy include physiologic anemia, neutrophilia, and reduced platelet count. There is also an increase in many of the factors of the clotting cascade leading to increased in vivo generation of thrombin. Unfortunately, there is not a similar increase in the endogenous anticoagulant factors: protein S activity decreases, and there is a resistance to activated protein C. The net effect is therefore one of thrombus formation. Furthermore, there is a decrease in the activity of the fibrinolytic system mediated by increased plasminogen activator inhibitor type 1 and increased type 2 produced by the placenta. These changes, in addition to the venous stasis that occurs as a result of the gravid abdomen, make pregnancy a hypercoagulable state with a 4 to 5 times increased risk of venous thrombosis.

**Connective Tissue**

Pregnancy requires significant changes in the musculoskeletal system to allow the muscles and joints of the pelvis to carry the developing fetus as well as prepare for delivery of the newborn. This requires changes in the laxity of the ligaments of the pelvic floor. The control of this process is under the control of the hormone relaxin, which increases until the 12th week of pregnancy and then declines until the 17th week, after which levels remain stable. Relaxin is associated with the remodeling of large diameter collagen fibers to small diameter collagen fibers. This process requires activation of the collagenolytic system. Elastin may also play a role in this process.

**Preeclampsia**

As discussed above, the decrease in systemic vascular resistance is a crucial adaptation that occurs during pregnancy, since it allows for the increase in cardiac output and plasma volume to occur with little maternal hypertension. When an increase in blood pressure does occur, there are a multitude of clinical scenarios. If a mother has a history of hypertension that predates pregnancy, it will continue to be an issue in pregnancy and is usually present before the 20th week of gestation or persists for longer than 12 weeks postpartum. Gestational hypertension is defined as mild hypertension that develops later in pregnancy and without signs of end organ damage. Although some mothers will have postpartum resolution of their hypertension, others develop preeclampsia. Preeclampsia is defined as the onset of hypertension after the 20th week of gestation in previously normotensive woman. It is associated with proteinuria and may progress to eclampsia with the development of grand mal seizures. Finally, a woman with chronic hypertension who develops proteinuria after the 20th week of gestation is considered
preeclampsia. One of the above clinical scenarios complicates 12% to 22% of pregnancies, with preeclampsia occurring in 8% of pregnancies in the United States. The issues of hypertension in pregnancy are increasingly important because the number of pregnant women more than 40 years of age has doubled in the past decade. This increasing maternal age obviously includes a population of women who will have chronic hypertension unmasked by the stresses of pregnancy or who have a preexisting diagnosis of hypertension. In addition, women who develop preeclampsia are at increased risk for other cardiovascular disorders later in life and may therefore be a population who needs more aggressive primary prevention.

Preeclampsia is one of the leading causes of maternal and fetal morbidity and mortality, with complications ranging from hepatic failure and stroke to HELLP syndrome (hemolysis, elevated liver enzymes, and low platelets) and fetal death. Risk factors for preeclampsia include multifetal gestation, obesity, pregestational diabetes mellitus, and thrombophilias. Although the exact pathogenesis of preeclampsia is not known, one might hypothesize that it shares a common mechanism with atherosclerosis, since they have many risk factors in common and affect similar populations. In fact, preeclampsia is a clinical syndrome of endothelial dysfunction that occurs in the setting of an ischemic placenta. Normal placental perfusion requires invasion of maternal spiral arteries by fetal cytotrophoblasts, which reduces the diameter of the muscular arteries, decreases their resistance, and enhances placental perfusion. The placenta becomes hypoxic either because of poor placentation, which occurs if the maternal blood supply is not well developed at an early stage, or because of microvascular disease native to the mother, which limits her ability to perfuse the placenta. Placental ischemia increases in the second trimester as the fetus requires increasing access to the maternal blood supply and is thought to initiate a systemic inflammatory response in the maternal circulation. This response includes the endothelial dysfunction thought to be mediated by high levels of the soluble receptor for vascular endothelial growth factor-1 as well as an immune-mediated component caused by a disturbed interaction between natural killer cells and cytотrophoblasts. Together, these lead to the clinical consequences of preeclampsia including enhanced platelet aggregation and decreased activity of vasodilators.

Using these theories as a starting point, many recent randomized trials have attempted to decrease the incidence of preeclampsia by the use of aspirin to treat the microvascular dysfunction or antioxidants to reduce oxidative stress. In a recent trial designed to evaluate the use of vitamin C and vitamin E to prevent preeclampsia, minimal to no benefit was seen. A systematic review of 39 randomized trials found that aspirin was associated with only a 15% reduction in the incidence of preeclampsia. Therefore, the management of preeclampsia still relies on early identification and careful monitoring of mothers with the disease. Delivery is always the best treatment if the fetus is at term. However, if women have disease at earlier stages of pregnancy, treatment depends on antihypertensive management and assessment of maternal-fetal conditions.

The treatment of hypertension during pregnancy is recommended for sustained systolic blood pressure higher than 160 and sustained diastolic blood pressure higher than 110 mm Hg. The choice of agent is made more difficult by the limited number of medications that are tolerated by the developing fetus. To lower blood pressure acutely, intravenous hydralazine is often used, although the safety of this medicine in pregnancy has recently been called into question. Other choices for antihypertensive medications include nifedipine, mehtyldopa, and labetalol. As long as the mother with isolated gestational hypertension or chronic hypertension is monitored closely during pregnancy and there is no evidence of proteinuria or other end organ damage, there is no evidence that treatment of mild to moderate elevations in blood pressure change outcome. Therefore, although women with any elevation of blood pressure during pregnancy must be monitored closely for evidence of severe disease or preeclampsia, they may not necessarily need chronic therapy.

**Acute Myocardial Infarction**

Myocardial infarction (MI) is a rare complication of pregnancy but may become increasingly
frequent as the maternal age increases. The incidence is in the range of 3 to 10 per 100,000 deliveries. In a population-based study, Ladner et al. examined California discharge records from 1991 to 2000 and found the incidence of MI to be increasing when they compared the later years with the earlier ones. In a United States population-based study, the group of mothers that had MI were older than the group with no MI (33 vs 27 years old). The strongest independent predictors of MI were chronic hypertension, pregestational diabetes, smoking, thrombophilia, and advancing maternal age. In addition, preeclampsia was also a strong predictor of MI, which is not surprising because these women are known to have endothelial dysfunction and platelet aggregation. James et al. found the maternal mortality rate of acute MI during pregnancy to be 5.1%. Ladner et al. also found the maternal mortality rate to be 7.3% and found that women who had an MI intrapartum had an even higher mortality of 19%. Because acute MI during pregnancy is predicted by the usual risk factors of age, diabetes and hypertension, one might hypothesize that they are mediated by atherosclerotic disease. However, a review of the literature indicates that only about 10% of women with MI are known to have preexisting atherosclerotic disease. Again, as the trend toward advancing maternal age continues, a mother with a preexisting diagnosis of coronary artery disease may be a more common scenario. There is little data for stress testing in pregnancy, and the use of cardiac catheterization may be limited out of fear of the risks of radiation on the developing fetus. The diagnosis of MI may not be suspected as often as it should, and there may be reluctance to intervene even when it is suspected. Therefore, the management of coronary artery disease in pregnancy is often medical. The use of aspirin is thought to be safe at doses of less than 200 mg/d. The use of angiotensin-converting enzyme (ACE) inhibitors is contraindicated because of known teratogenic effects. There is limited data on chronic β-blocker therapy, but some studies suggest that they may cause intrauterine growth delay. At the time of delivery, supportive care is indicated to reduce myocardial oxygen demands. Epidural anesthesia may reduce pain and therefore tachycardia, and nitrates, oxygen, and β-blockers should be used.

In addition to atherosclerotic disease, acute MI may be a result of spontaneous coronary artery dissection. A recent review of the literature indicates 58 cases of spontaneous coronary dissection. Thirteen cases occurred during pregnancy, with 45 cases occurring in the postpartum period, most in the 2 weeks after delivery. The mechanism by which dissection occurs in otherwise normal coronary arteries is unknown, but the hemodynamic stresses of pregnancy have been implicated. There is fragmentation of reticulin as well as other changes in the media of the vessel that may predispose the vessel to dissection. The treatment of coronary artery dissection ranges from medical therapy with intravenous heparin to percutaneous intervention and even cardiopulmonary bypass surgery. The mortality found in the recent review of the literature was high at 38% of overall cases.

Finally, acute MI during pregnancy may have an embolic cause. This may occur secondary to mechanical valve thrombosis or could occur secondary to venous thrombosis in the setting of a patent foramen ovale. Another cause is coronary vasospasm. Although coronary vasospasm is rarely a cause of acute MI outside of pregnancy, among 68 cases of pregnancy-related acute MI with known coronary anatomy, 29% had normal coronary arteries, suggesting coronary vasospasm.

Cerebrovascular Events

Stroke is a devastating complication of pregnancy, both because of the high incidence of maternal mortality and because of the disability that results for the mother of a newborn. In a recent analysis of the pregnancy-related discharges from the Nationwide Inpatient Sample, the incidence of stroke was 34.2 per 100,000 deliveries with a case fatality rate of 1.4 per
100,000 deliveries. This represents a 3-fold increase in the risk of stroke when compared with nonpregnant women of the same age. The timing of the cerebral vascular accident (CVA) was almost equally divided between intrapartum and postpartum, with only 11% being antepartum. Risk factors that were identified in this analysis were a history of migraine headaches, thrombophilia, systemic lupus erythematosus, and heart disease. The association with migraine headaches is an interesting one, since patent foramen ovale has been implicated in the pathophysiology of migraine headaches and cryptogenic stroke. Perhaps the history of migraines identifies a subset of pregnant women with patent foramen ovale at higher risk of paradoxical emboli. In addition, the changes in body habitus that are associated with pregnancy could change the anatomy of the atrial septum and make the risk of paradoxical emboli greater. Patent foramen ovale (PFOs) has been implicated as the etiology for stroke during pregnancy, and there is even a report of PFO closure in a pregnant patient with recurrent CVA. This is assuming, of course, that the association between migraine and PFO leads primarily to ischemic stroke.

The treatment of pregnancy-related ischemic stroke is limited because the use of anticoagulation, especially thrombolytic therapy, may cause placental abruption or hemorrhage and place the fetus at risk for preterm labor and demise. A recent report examined 8 cases of acute ischemic stroke in pregnancies that were treated with intravenous tissue plasminogen activator (tPA). Although 3 of the patients had medical termination of pregnancy, 2 had miscarriages and 2 delivered healthy babies. It should be noted that 7 of the 8 cases involved pregnancy in the first trimester, whereas most pregnancy-related stroke occurs in the intrapartum and postpartum periods. Only 1 patient was treated with tPA at 37 weeks and delivered a healthy baby. Nevertheless, the use of intravenous tPA is not well supported by evidence and the teratogenic effects are unknown. Another option that is increasingly common in the treatment of acute ischemic stroke is the use of intra-arterial tPA. This localized treatment reduces the systemic effects of thrombolytic therapy and may therefore reduce the risk of bleeding complications. There is one report in the literature of a 39-year-old woman at 37 weeks gestation who presented with a complete left-sided hemiparesis and was found to have right middle cerebral artery occlusion; this was successfully treated with intra-arterial tPA. She was induced the following day, delivered a healthy baby boy, and went on to a full neurological recovery. Obviously, further work is necessary, but a potentially safe treatment may be available for mothers who have ischemic stroke.

Most of the strokes that occur in pregnant women are secondary to other complications such as the hypertensive disorders of pregnancy, and hemorrhagic stroke is the most common cause of death in patients with eclampsia. Women with preeclampsia frequently do not receive antihypertensive therapy unless their diastolic blood pressure is higher than 105 mm Hg. However, a recent analysis of the incidence of stroke in the setting of preeclampsia by Martin et al indicates that most patients never reached this threshold before cerebral hemorrhage. The article, therefore, argues that systolic blood pressure must also be considered and that women with systolic blood pressure higher than 160 mm Hg in the setting of endothelial dysfunction found in preeclampsia might benefit from antihypertensive therapy.

Although 30% to 44% of pregnancy-related hemorrhagic stroke is related to preeclampsia/eclampsia, there are other important causes, including cerebral venous thrombosis (CVT), subarachnoid hemorrhage (SAH), and primary intracerebral hemorrhage (ICH). Cerebral venous thrombosis occurs in about 11 per 100,000 deliveries and in a large series of CVT cases, 20% occurred in women with age less than 50. Thrombosis of the cerebral veins or sinuses can lead to venous backflow and subsequent ICH. Cerebral venous thrombosis may occur at any time during pregnancy, but the most common timing is postpartum. Even in the presence of ICH from CVT, this disorder is treated with anticoagulation for at least 3 to 6 months. Subarachnoid hemorrhage occurs as a result of aneurysm or arteriovenous malformation rupture. Nonaneurysmal SAH may be related to vasculopathy in the setting of severe hypertension, but the incidence of this rare subtype is unknown. Up to one half of all ruptured aneurysms in women with age less than 40 are
related to pregnancy. Aneurysmal and arteriovenous malformation rupture during pregnancy may be related to the dilation of abnormal blood vessels in the setting of rising estrogen levels. Pregnancy-related ICH is generally associated with severe hypertension and is also associated with advanced maternal age, African American race, coagulopathy, and tobacco abuse. Pre-
gancy-related ICH is a major cause of maternal death and accounted for 7% of all pregnancy-related mortality in a recent report. Treatment of SAH and ICH is generally supportive but should involve the expertise of a neurointensivist or a neurosurgeon. Blood pressure control and maternal monitoring for elevated intracranial pressure, cerebral edema, and neurological deterioration are all mainstays of treatment.

Venous Thromboembolism

Venous thromboembolism (VTE) and its associated complications are another important cause of maternal morbidity and mortality with an estimated incidence of 1 to 2 per 1000 deliveries. Although arterial thromboembolism (acute MI and cerebrovascular events) accounts for 50% more deaths in pregnancy than VTE, VTE is 4 times more common. In addition to the hypercoagulability of pregnancy, the risk of VTE may be increased secondary to the venous stasis generated by the gravid uterus resting on the inferior vena cava. Many thrombophilias remain undiagnosed until pregnancy, when they present as deep venous thrombosis or pulmonary embolus (DVT/PE). In fact, thrombophilias are found in up to 50% of cases of VTE in pregnancy. The risk of venous thrombosis is also increased by other concurrent risk factors such as advanced age, bed rest required for the safety of the fetus, or cesarean delivery. According to recent studies, the risk of VTE is evenly distributed throughout all trimesters.

Once diagnosed, the treatment of VTE is dependent on the gestational age of the fetus. Anticoagulation with coumadin, the traditional treatment, is limited by its teratogenic and other harmful fetal effects. Warfarin embryopathy is characterized by nasal hypoplasia and stippled epiphyses and is thought to occur in up to 30% of infants exposed during the first trimester. Treatment with warfarin later in pregnancy is associated with central nervous system abnormalities and the risk of fetal hemorrhage. Although these complications occur at low rates, most physicians avoid treatment with warfarin in pregnancy altogether.

Heparins, both unfractionated and low molecular weight, do not cross the placenta and are therefore the best option for anticoagulation with respect to the safety of the fetus. However, the dosing of both medicines is difficult during pregnancy and may place the mother at risk for further events since appropriate anticoagulation may be difficult to maintain. In the case of pulmonary embolism, most experts recommend an initial treatment with intravenous unfractionated heparin. After a short course of intravenous therapy, the patient can be converted to subcutaneous low-molecular-weight heparin (LMWH) with dosing every 12 hours to achieve a therapeutic anti–factor Xa level. In the case of deep vein thrombosis, patients may be started on either intravenous unfractionated heparin or subcutaneous LMWH. Anti–factor Xa levels should be monitored monthly to ensure appropriate anticoagulation, as the required dose will change with the increase in weight and blood volume during pregnancy. The level of anticoagulation can be monitored by measuring anti–factor Xa levels to achieve a level of 0.5-1.2 U/mL 4 to 6 hours after the morning dose. Experience indicates that LMWH is not inferior to unfractionated heparin, and LMWH has become the anticoagulant of choice in pregnancy. It is also administered subcutaneously and is given twice a day. Because LMWHs achieve a more consistent level of anticoagulation than unfractionated heparin, they can be dosed using a weight-based formula, and frequent blood work may be avoided.

Treatment of VTE should continue throughout pregnancy and for at least 6 weeks postpartum. As with all anticoagulation, there is an increased risk of maternal bleeding. If significant bleeding limits the use of anticoagulation, the remaining option for the treatment of VTE is placement of an inferior vena cava filter. It may be placed temporarily and removed once full-dose anticoagulation can be safely resumed. Ideally, anticoagulation should be discontinued 24 hours before delivery. Therefore, most women should be scheduled for induction close to
term and have their anticoagulation discontinued. Once the baby is delivered, anticoagulation can be resumed for the postpartum period.\textsuperscript{52}

If DVT is suspected in a pregnant patient, ultrasound of the lower extremities is the diagnostic modality of choice and is safe for both fetus and mother. However, if there is a question of PE, diagnosis can be more difficult because most diagnostic testings to rule out PE relies on the use of radiation. In some situations, the presence or absence of PE will not change treatment, and therefore, once DVT is established, therapy with anticoagulation can be initiated. If, however, there is hemodynamic instability, it may be more crucial to definitively diagnose PE. Ventilation-perfusion scanning is considered safe to perform during pregnancy with all isotopes. However, helical computed tomography is the more common imaging used in nonpregnant patients and may be more reliable in the diagnosis of acute PE. Recent studies have suggested that the amount of radiation used in a helical computed tomography is safe for the developing fetus because the images are obtained quite rapidly, but the same amount of radiation is obtained during a pulmonary angiogram, the gold standard for the diagnosis of PE. Thus, some might argue to proceed directly to angiography. Echocardiography can also be used to safely diagnose right heart strain in the pregnant patient, which should be present in the patient hemodynamically unstable secondary to a PE.\textsuperscript{55}

If a pregnant mother is found to be hemodynamically unstable secondary to VTE, therapy is predominately supportive. Volume is important because right heart failure is the predominant mechanism of low cardiac output in these patients. If vasopressors are required, the use of predominately $\beta$ agonists may be the most appropriate because the stimulation of $\beta$ receptors in the uterus relaxes uterine muscle tone and does not affect uterine blood flow.\textsuperscript{55} Recent work in the anesthesia literature suggests that the best combination to treat hypotension may be the use of phenylephrine and volume resuscitation because there is vast experience with phenylephrine in pregnancy and no risk of fetal acidosis. This regimen would also be appropriate to treat the right heart failure associated with PE.\textsuperscript{56} The use of thrombolytics is reserved for cases of impending maternal death, since there is little data to support its safe use in pregnancy. Surgical embolectomy is associated with a high rate of fetal loss (20%-40%).\textsuperscript{55}

**Amniotic Fluid Embolus**

Amniotic fluid embolus is an exceedingly rare but devastating complication of pregnancy, the cause of which is unknown. Hypotheses for its pathophysiology involve a simultaneous tear in the uterine vessels and amniotic sac, which allows the entrance of amniotic fluid into the maternal circulation, predominately the pulmonary arteries. The amniotic fluid is thought to contain immunologically active and vasoactive substances that cause intense pulmonary arterial vasoconstriction and resulting hypoxia. The subsequent release of inflammatory substances sets in motion a cascade that is similar to the systemic inflammatory response syndrome and may end in cardiac arrest.\textsuperscript{57} Amniotic fluid embolus classically occurs during labor and delivery or immediately afterward and is identified by the presence of hypoxia, hypotension, altered mental status, and disseminated intravascular coagulation. The first challenge is to diagnose the cause of the cardiovascular collapse, since a similar syndrome can be caused by PE or septic shock. Amniotic fluid embolism is predominately a diagnosis of exclusion because there are no specific laboratory tests or diagnostic modalities. A recent population-based study of amniotic fluid embolus identified associated risk factors including maternal age more than 35 years, polyhydramnios, eclampsia, cervical laceration/uterine rupture, and medical induction of labor.\textsuperscript{58} Treatment is predominately supportive with volume, transfusion, inotropes, and oxygen/mechanical ventilation. Despite the severity of the clinical syndrome, a recent study indicated a mortality of only 26%.\textsuperscript{59}

**Peripartum Cardiomyopathy**

Peripartum cardiomyopathy (PPCM) is a disorder of left ventricular (LV) dysfunction that occurs between the last month of pregnancy and the first 5 months postpartum. Women present with the typical clinical syndrome of dyspnea, lower extremity edema, orthopnea, and abdom-
inal swelling. Many of these same symptoms can be seen in the late stages of pregnancy as well, so one must be careful to examine patients closely for signs of volume overload such as pulmonary edema or a gallop heard on cardiac examination. If these are present or there is other reason for concern, the patient may be referred for echocardiography to assess LV function. If LV dysfunction is present, then the next step is to rule out other causes for cardiomyopathy such as thyroid disease, autoimmune disorders, ischemic disease, or HIV. Peripartum cardiomyopathy is predominately a diagnosis of exclusion because there is no definitive diagnostic testing.

The etiology of PPCM is unknown, but there is growing evidence that the mechanism is one of autoimmunity. Recent work on inflammatory markers in patients with PPCM demonstrated a higher level of tumor necrosis factor and fas ligand in patients with the disease and also showed that the level of these inflammatory markers correlated with the level of ventricular dysfunction. In addition, work by Ansari et al. has demonstrated the presence of antibodies against cardiac proteins in the sera of women with PPCM. These antibodies were not present in women with idiopathic dilated cardiomyopathy. Other suspected causes include viral triggers and nutritional deficiency. Despite these recent advances, much more work is needed before this disease is fully understood.

Once diagnosed, the management of these patients is similar to that of patients with other forms of cardiomyopathy. Diuretics are used to improve the symptoms of volume overload, whereas β-blockade and ACE inhibition are used to optimize hemodynamics and improve mortality, if the cardiomyopathy occurs in the postpartum period. If the pregnancy is ongoing, a regimen of hydralazine and nitrates is used for afterload reduction, since ACE inhibitors should be avoided. The delivery of the fetus as soon as possible is important in these patients because it is feared that LV function will continue to deteriorate in the setting of continued pregnancy. Because of the hypercoagulability of pregnancy, coupled with the risk of thrombus in the failing heart, many recommend the use of anticoagulation for these patients, although there is little data to support this. Fortunately, about a third of women with PPCM have spontaneous recovery of LV function after delivery when treated with medical therapy. However, these women are counseled to avoid additional pregnancies. Elkayam et al. found that symptoms of heart failure recurred in 21% of those who entered a second pregnancy with a normal ejection fraction and 44% of those patients who entered a second pregnancy with baseline LV dysfunction. Thus, the syndrome can return with subsequent pregnancy and may have more severe manifestations the second time.

**Aortic Aneurysm and Dissection**

As noted earlier in this review, there is considerable activation of the collagenolytic system during pregnancy as the body prepares for delivery of the fetus through the pelvis. This increased lysis of collagen has ramifications for the vasculature as well, especially in patients who have preexisting collagen defects such as Marfan, Ehlers-Danlos, or the cystic medial necrosis that is sometimes seen in the setting of bicuspid aortic valves. Many of these patients have dilatation of their aortic root, which places them at risk for spontaneous rupture and dissection. In the nonpregnant patient, there is a role for conservative management until the aortic root is greater than 5.5 cm in diameter. However, the additional stresses of pregnancy lower the threshold for intervention. In young women with dilatation of the aortic root associated with congenital heart disease, pregnancy is well tolerated at dimensions of less than 50 mm in diameter. Once the root is more than 50 mm, surgical intervention is recommended before pregnancy. These criteria are stricter in the setting of Marfan, in which aortic roots more than 40 mm are associated with cardiovascular complications. Patients with Marfan syndrome and aortic roots more than 40 mm are counseled to avoid pregnancy until surgical repair.

**Conclusion**

There is considerable stress on the cardiovascular system in the setting of pregnancy, and the adaptations required are much more involved than an increase in blood volume and cardiac output. Many organ systems ranging
from the hematologic system to the immunologic system are required to make major adaptations to the physiology of pregnancy; if they are unable to make these changes, complications that affect the cardiovascular system result. The morbidity associated with these complications and the increased incidence seen with advanced maternal age make the understanding of these complications imperative. In addition, these patients require an interdisciplinary team including neurologists, cardiologists, surgeons, and obstetricians, and all members must understand the complicated medical and emotional issues at hand.

References

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