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Cardiac imaging and functional assessment in pregnancy

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ABSTRACT

There are multiple imaging modalities available for the assessment of pregnant women with known or suspected cardiac disease. Because of its safety and general availability, echocardiography is the preferred study of choice for the evaluation of ventricular function, valvular heart disease, congenital heart disease, evaluation of the aorta, and the estimation of cardiac hemodynamics in a pregnant patient. Cardiac MRI can be performed, especially for diseases of the aorta and complex congenital heart disease. Radiation exposure for the fetus and the mother will be discussed in the use of CT angiography, nuclear imaging, and left-heart catheterization including coronary angiography for specific indications in the pregnant woman. The use of exercise testing during pregnancy for functional assessment will be presented.

Introduction

For the pregnant woman with suspected heart disease, a number of diagnostic imaging modalities are available to evaluate cardiac anatomy and function. These include echocardiography, cardiac MRI, CT scanning, nuclear imaging, and right- and left-heart catheterization. Indications and safety concerns will be reviewed. Management of the patient should be optimized by consultation with the appropriate specialists before diagnostic testing is undertaken. Ideally, women with known heart disease, collagen vascular diseases such as Marfan syndrome, or women with potential heart disease (prior chemotherapy, prior radiation, etc.) should undergo assessment prior to pregnancy to help establish their potential risks prior to conception, but many patients will present in pregnancy without a pre-pregnancy cardiac evaluation. For the pregnant woman with known or suspected heart disease, a functional assessment, in addition to a detailed history, may be important. The use of cardiac stress testing will also be discussed.

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Echocardiography

Transthoracic echocardiography

Because of its general availability and safety, transthoracic echocardiography is by far the preferred diagnostic test for cardiac imaging[1] when a cardiac diagnosis is suspected. A transthoracic echocardiogram provides information about ventricular function, valvular abnormalities, abnormalities of the aorta, and congenital abnormalities and can provide an estimation of right-sided cardiac pressures.

Indications

1. A transthoracic echocardiogram should be obtained in a pregnant woman with cardiac complaints including shortness of breath out of proportion to what is expected in a normal pregnancy, chest pain, unexplained syncope, or palpitations. Cardiac symptoms are common in normal

Table 1 – Predictors of cardiovascular risk identified by the CARPREG investigators.

Predictors for maternal cardiovascular events
Prior cardiac events (heart failure, transient ischemic attacks, or stroke) or arrhythmias
Poor functional class or cyanosis
Left-heart obstruction (MVA <2 cm^2, AVA <1.5 cm^2, peak LVOT gradient >30 mmHg)
Left ventricular systolic function (ejection fraction $<40\%$)
A point is assigned for each abnormality above. 0 point is low risk (5%), 1 point is intermediate risk (27%) and >1 point is high risk (75%)
Patients with prosthetic valves requiring anticoagulation, patients with pulmonary hypertension, and patients with dilated aortas are considered to be high risk.[1]

pregnancy, so a heightened suspicion of a possible underlying cardiac problem in patients at risk is warranted.

2. A pregnant woman presenting with or with a history of a documented arrhythmia such as atrial fibrillation or flutter or ventricular arrhythmias as these may be a marker of previously unknown cardiac disease.
3. Known heart disease in a pregnant woman who did not have a prenatal echocardiogram for risk stratification prior to pregnancy. The risk score developed by Siu for the CARPREG investigators[2] used information obtained from transthoracic echocardiography for a wide range of cardiac diseases. Table 1 summarizes the risk stratification based on the factors identified by the CARPREG investigators to predict cardiovascular risk in pregnant women.

A pregnant woman with pre-existing hypertension who is suspected of having hypertensive heart disease.[3]

4. A pregnant woman with a stroke of unknown etiology. The safety of saline contrast bubble studies for patients with suspected patent foramen ovale has not been studied/established during pregnanzcy. Colletti and Elkayam[4] in a recent review stated that saline contrast microbubbles can be used. Left ventricular contrast agents (perflutren-containing human microspheres) used primarily for better visualization of the left ventricle or for cardiac masses are category C drugs and should not be used.
5. A prior history of chemotherapy or radiation in a woman who did not undergo a pre-pregnancy cardiac evaluation.

Table 2 summarizes the role of transthoracic echocardiography in pregnancy.

Table 2 – Information provided by echocardiography and clinical indicators.

Information provided by echocardiogram
Ventricular function
Valvular abnormalities
Congenital heart disease
Estimation of cardiac pressures
Measurement of aortic size
Clinical indications
Symptoms of shortness of breath, chest pain, syncope, and palpitations
Documented arrhythmias
Known heart disease to establish CARPREG score if not done prior to pregnancy
Hypertension/hypertensive heart disease
Stroke
History of prior radiation or chemotherapy

Serial echocardiography, rather than a single study, may be indicated during pregnancy depending on the underlying cardiac abnormality. For example, for women with dilated aortic roots or enlarged ascending aortas, monthly or bimonthly echocardiographic studies are recommended according to current guidelines.[1,5] Transthoracic echocardiography has been used to study the normal hemodynamic changes during pregnancy as well.[6–9] A recent study by Savu et al.[8] showed that normal pregnancy is associated with increases in left ventricular and right ventricular chamber sizes, an increase in left atrial size, and physiologic eccentric hypertrophy (increase in wall thickness). However, left ventricular ejection fraction did not change. The value of echocardiography in the assessment of cardiac disease in pregnancy has been reviewed by Tsiaras and Poppas.[10]

Transesophageal echocardiography

Maternal echocardiography using a transesophageal approach is relatively safe during pregnancy[1] although its use should be restricted to circumstances where a transesophageal study is necessary such as before/during mitral balloon valvuloplasty or where the findings would alter the management of the patient during pregnancy (aortic dissection in settings when other modalities are not available). Pregnancy causes changes in esophageal and gastric motility, which leads to slower transit times.[11] Pregnant women have a high risk of vomiting and aspiration, and sudden changes in intra-abdominal pressure may occur with the performance of a transesophageal echocardiogram.[1] Sedation may best be handled with the help of an anesthesiologist, and fetal monitoring will be required if at a viable gestational age.

Cardiac magnetic resonance imaging (MRI)

If ultrasonography cannot provide adequate diagnostic information, and better imaging is required to optimize management of the pregnancy, cardiac MRI can be performed during pregnancy.[12–15] According to the ESC guidelines,[1] cardiac MRI may be particularly helpful in the assessment of complex congenital heart disease and for diseases of the aorta. Although the safety of MRI during pregnancy has not been firmly established, no deleterious effects on the fetus have been reported.[12–15] The main safety concerns include potential teratogenicity and acoustic damage.[12–15] Imaging should be avoided in the first trimester if possible.[1] The use of gadolinium, a class C drug, should be avoided.[12–15]

Table 3 – Estimated fetal and maternal effective doses for various diagnostic and interventional radiology procedures.

Procedure	Fetal exposure		Maternal exposure	
Chest radiograph (PA and lateral)	<0.01 mGy	<0.01 mSv	0.1 mGy	0.1 mSv
CT chest	0.3 mGy	0.3 mSv	7 mGy	7 mSv
Coronary angiography [a]	1.5 mGy	1.5 mSv	7 mGy	7 mSv
PCI or radiofrequency catheter ablation [a]	3 mGy	3 mSv	15 mGy	15 mSv

CT = computed tomography; PA = posteroanterior; PCI = percutaneous coronary intervention.
Reprinted with permission from Oxford University Press.
[a] Exposure depends on the number of projections or views.

Cardiac computed tomography (CT) scan

CT pulmonary angiography is the preferred diagnostic test for suspected pulmonary embolism in pregnant women[1] according to the European guidelines, although nuclear ventilation–perfusion imaging is a reasonable alternative. The expertise existing at a given institution might determine which test is used. A study by Lazarus et al.[16] showed a marked increase in the use of CT angiography for the diagnosis of pulmonary embolism in pregnant women compared with nuclear imaging in the 10-year period from 1997 to 2006. CT scanning may also be used to confirm the diagnosis of aortic dissection if MRI and transesophageal echocardiography are not available and in trauma cases where aortic disease is suspected.

Safety issues with CT vary with gestational age and include radiation exposure of the mother and the fetus and the effect of contrast agents on the developing fetus. This topic is discussed extensively in two reviews on the safety of imaging during pregnancy.[4,15] Fetal risks of anomalies, growth restriction, or spontaneous abortions do not appear to be increased with radiation exposure of less than 5 rad, a level that is above the range of exposure for diagnostic procedures.[16] In diagnostic imaging, different units can be used; the equivalencies are as follows: 5 rad = 5 rem = 50 mGy = 50 mSv.[15] The following table from the European Guidelines on the management of cardiovascular diseases during pregnancy shows the estimated fetal and maternal doses for several cardiac procedures (Table 3).

In a review by Colletti et al.,[4] the fetal and maternal doses of radiation of CT angiography versus ventilation–perfusion scanning in a pregnant patient were presented (Table 4).

In an extensive review on the use of diagnostic imaging for acute pulmonary embolism in pregnancy, Pahade et al.[17] use Table 5 to demonstrate the various radiation exposures for various exams performed for pulmonary embolism.

In a pregnant patient requiring imaging, radiation dose reduction methods should be implemented.[18] The currently used low-osmolality iodinated contrast agents are category B drugs and can be used when needed.[4] Iodinated contrast agents are known to cross the placenta and enter the fetus.[19] The current recommendation is that contrast be used only when benefit outweighs potential risks.[4,15,20]

Cardiac catheterization

Right-heart catheterization

Although echocardiography can provide an estimate of right-sided pressures, right-heart catheterization may be necessary to accurately measure the pulmonary artery pressure and the pulmonary vascular resistance if management of the patient is to be altered. In a small study at our institution, although there was a good correlation between the estimated RVSP and the measured PA pressure, right-heart catheterization eliminated the concern for pulmonary hypertension in 30% of the patients.[21] Right-heart catheterization requires minimal or no fluoroscopy. A more complex right-heart catheterization would be required for the performance of a balloon pulmonic valvuloplasty.

Left-heart catheterization

Left-heart catheterization would be required in women with valvular heart disease undergoing mitral balloon valvuloplasty or aortic valvuloplasty. These procedures would be undertaken in pregnancy only in highly symptomatic women presenting with heart failure.

Coronary artery disease

It is uncommon that coronary angiography and coronary interventions would be required during pregnancy. Coronary

Table 4 – Comparison of imaging strategies for pulmonary embolism in a pregnant patient.

Characteristics	Pulmonary CT angiography	Ventilation–perfusion scintigraphy[a]
Accuracy	High	High (with pulmonary CT angiography backup)
Availability	High	Low
Efficiency	<1 h	Several hours
Expense	High	High
Reliability	High (may be reduced in pregnancy)	Moderate (3–25% nondiagnostic)
Risks	Iodinated contrast agent	
Fetal dose (mGy)	0.01–0.66	0.1–0.8
Maternal breast dose (mGy)	20–70	0.22–0.28

Reprinted with permission from the American Journal of Roentgenology.
[a] Pulmonary CT angiography may be required if ventilation–perfusion scanning is nondiagnostic.

Table 5 – Imaging of pregnant and lactating patients: Radiation exposure of various imaging examinations performed for pulmonary embolism.

Examination	Effective whole-body dose (mSv)	Fetal dose (mGy)	Effective dose per breast (mGy)
Posteroanterior or lateral chest radiography	0.06–0.25	0.01	
Low-dose perfusion scintigraphy	0.6–1.0	0.1–0.37	0.11–0.3
Ventilation–perfusion scintigraphy	1.2–6.8	0.1–0.8	0.22–0.28
Pulmonary CT angiography	2–20	0.01–0.66 [a]	10–70
Low-dose pulmonary CT angiography	2.7		
Pulmonary digital subtraction angiography	3.2–30.1	0.5	
Evaluation of background radiation	2.5	1.1–2.5	

Note variation in reported doses is largely related to CT settings, number of CT detectors, trimester, patient age, body mass index, and method of dose calculation.

[a] Data from Winer-Muran et al. [24] not included due to outdated CT parameters and generation of CT scanner used in this study. (Reprinted with permission from Pahade et al.[17])

artery disease may be present in young women who have previously received chest radiation for lymphoma. Women may have received coronary stents for prior coronary dissection or for premature coronary artery disease from familial lipid disorders. Spontaneous coronary artery dissection can occur in women during pregnancy.[22,23] It is also recognized that women are delaying childbearing until they are older, increasing the risks for acquired heart disease. Statistics from 2009 showed that the only age-specific increase in birth rate occurred in women aged 40–44 years.[24] The birth rate for women 45–49 years of age has trended upward since 1992.[24] Older women have a higher likelihood of hypertension, diabetes, and underlying cardiovascular disease[25] so it is possible that the incidence of coronary artery disease will increase as women delay childbearing until their 30's or 40's. Myocardial infarction can also occur during pregnancy,[26,27] and although uncommon, it is more likely to occur in older women and overall has a maternal mortality rate of 7.3%. Table 3 shows the radiation associated with coronary angiography and coronary interventions that might be required in this population.

Nuclear imaging

Except for ventilation–perfusion imaging for the diagnosis of pulmonary emboli discussed above, most other nuclear imaging studies (myocardial perfusion studies and PET perfusion/viability studies) are not performed during pregnancy because of the concern for exposure to radiopharmaceuticals.[4] For stress testing that requires imaging, echocardiography would be preferred over nuclear imaging in pregnancy.

Exercise testing

Occasionally pregnant women with known or suspected cardiac disease will require a more extensive functional assessment. In the general population, exercise testing is often used to assess exercise tolerance and to evaluate for symptoms such as chest pain or heaviness. Ideally, this should occur before pregnancy whenever possible. Liu et al.[28] exercised a group of women with congenital heart disease before pregnancy and showed that an abnormal chronotropic response was predictive of adverse pregnancy outcomes. There have been no studies looking at the predictive value of pre-pregnancy stress testing in women with known valvular heart disease or cardiomyopathies for adverse outcomes. The safety of exercise testing in pregnant women has been studied. MacPhail et al.[29] performed maximum exercise testing in late gestation in 23 active women and showed no abnormal fetal bradycardic responses in normally grown fetuses and no adverse neonatal outcomes. Szymanski and Satin[30] performed exercise testing in inactive, regularly active, and vigorously active healthy women between 28 and 32 weeks of gestation and showed no untoward fetal outcomes using the umbilical artery Doppler systolic-to-diastolic ratio as the primary outcome measure of fetal well-being measured after exercise. Heenan et al.[31] performed cardiopulmonary exercise testing in 14 women in late gestation and showed no change in work efficiency. There were alterations in energy metabolism and acid–base regulation that appeared protective for the maintenance of fetal well-being during strenuous exercise. Again, if imaging is required with stress testing, exercise echocardiography is preferred over nuclear imaging studies because of the radiation exposure and radiopharmaceutical agents required for the latter.[1,4]

There is no information as to the safety of the use of dobutamine stress echocardiography during pregnancy for women who are unable to exercise. Dobutamine is a class B drug,[4] and its use has been associated with hypotension, hypertension, coronary spasm, and arrhythmias including ventricular tachycardia and supraventricular tachycardia.[32] Fortunately, life-threatening complications are rare.[32] The European guidelines on the management of cardiovascular diseases during pregnancy[1] state that dobutamine stress testing should be avoided whenever possible. However, dobutamine stress testing has been used to test myocardial reserve in postpartum women with a history of peripartum cardiomyopathy.[33,34]

Summary

Cardiac imaging and an assessment of heart function can be very useful when managing patients with a history of cardiac

disease or women who present with new cardiac complaints during pregnancy. Various imaging modalities are available to help the clinician optimally diagnose and manage cardiac disease in the pregnant patient.

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