Healthy Heart

Volume-2 | Issue-17 | April 5, 2011

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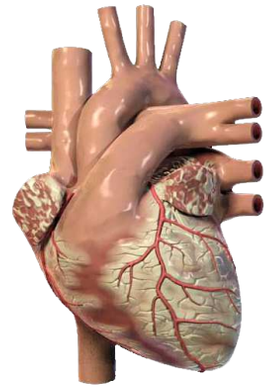

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From the desk of editor:

Coronary artery disease (CAD) comprises a spectrum of conditions that ranges from a totally asymptomatic status at one end to sudden cardiac death at the other. The development and widespread use of cardiac imaging techniques have contributed to the improvement in evaluation of patients with known or suspected CAD. Use of new imaging techniques before, during and after cardiac intervention, has improved outcome of cardiac procedures substantially. Since a wide array of new imaging techniques like contrast echo, 3D echo, tissue doppler, calcium score, PET scan and IVUS are available, it is dilemmatic for clinicians to decide the right investigation technique leading to right outcome. Use of non-judicious techniques affects the medical practitioners as well as patients. For deciding the right imaging technique, merits and demerits of each investigation should be considered before advocating its use. Sensitivity and specificity of any diagnostic test advocates its use. Some investigations like resting ECG though simple, may not be very sensitive and specific for detection of coronary artery disease like coronary angiography (though invasive) which is more reliable. In this 'Healthy Heart' article, merits and demerits of investigation techniques to be used for diagnosis in day to day practice are discussed.

Dr. Urmil Shah

Merits and Demerits of Newer Cardiac Imaging Techniques for Evaluation of CAD

Extent of coronary blockage & its physiological significance along with LV function and viability are important parameters for clinicians while dealing with patients of CAD.

Table 1: Test for Assessing Coronary ArteryDisease

Table 1: Test for Assessing Coronary Artery Disease	
Application	Test
Left ventricular function	- Echocardiography - Radionuclide imaging - ECG Gated MRI
Coronary artery disease diagnosis and prognosis	- Exercise or pharmacologic stress testing with ECG, myocardial perfusion imaging, or echocardiography - ECG Gated MRI - Coronary angiography ± IVUS - MDCT coronary angiography
Myocardial viability	- SPECT - Stress testing with echocardiography - PET Scan - ECG Gated MRI

[ECG: Electrocardiography, MRI: Magnetic Resonance Imaging, IVUS: Intravascular Ultrasonography, MDCT: Multidetector-Row Computed Tomography, SPECT: Single-Photon Emission Computed Tomography, PET: Positron Emission Tomography]

Echocardiography

Compared with other noninvasive techniques, it is the most versatile and provides information at the lowest cost. It does not use radiation. One can have real time assessment, allow rapid interpretation, can be repeated and is portable. The disadvantage is that the success of imaging varies from machine to machine, and is, in part, dependent on the sonographer expertise, and in technically difficult studies (e.g., obese patients) and in emergency room.

2D Echocardiography remains the first choice in the assessment of wall motion, LV size and function, mitral regurgitation, and assessment of diastole dysfunction which may be early sign of

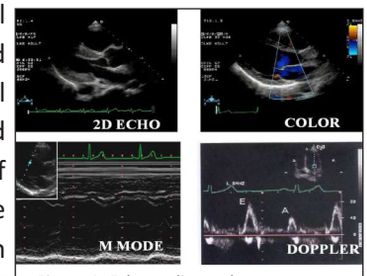


Figure 1: Echocardiography

CAD. Disadvantage of echocardiography is that visual assessment of wall motion and thickening requires significant expertise and involves some inter-observer variability, especially in lower quality images.

Echo can be normal in patients with significant CAD. Tissue doppler, Stress Echo, Contrast echo, 3D Echo and have distinct advantage over 2D Echo for diagnosis of CAD.

a) Tissue Doppler and Strain Imaging

With high end machine, tissue motion with low velocity can be measured. It provides more accurate assessment of diastolic function and regional wall abnormalities. Relaxation abnormality of heart is detected by tissue Doppler and has been correlated with long term prognosis. Strain imaging, an emerging technique in echocardiography, provides valuable tools in the understanding and assessment of the basics of myocardial properties and mechanics.

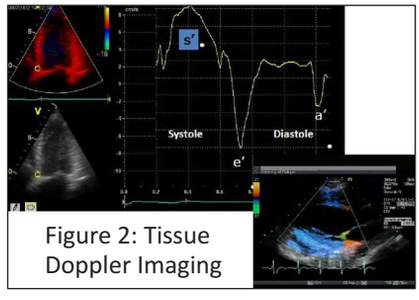


Figure 2: Tissue Doppler Imaging

b) Stress Echocardiography

During stress echocardiography, increased oxygen demand can be achieved through exercise or administration of adrenergic β-agonist (dobutamine) or a vasodilator (typically, dipyridamole). Stress echocardiography (Dobutamine) has 84% sensitivity and 75% specificity for diagnosis of coronary artery disease - better than exercise treadmill test. For single vessel disease and multivessel disease accuracy of stress echocardiography is 54-94% and 85-100%, respectively. It is very useful when exercise treadmill can't be done because of joint or spine problem or in a bed ridden patient. Normal stress echo has good long term prognosis. Addition of tissue Doppler and strain imaging increases accuracy of stress echo and reduces subjective error due to visual assessment of Regional Wall Motion Abnormalities (RWMA).

c) Contrast Echocardiography

Contrast echocardiography using micro-bubbles of perfluorocarbon gas, which passes through pulmonary and myocardial capillaries is useful in patient with CAD. It enhances LV border detection, LV volume and LVEF determination. It is especially helpful in assessing wall motion abnormalities, patients with poor Echo window, patient on ventilator and patient in emergency room. It is indicated in patients with suspected LV thrombus.


Figure 3: Contrast Echocardiography

d) 3D Echocardiography

3D echocardiography provides more accurate volumetric measurement of Left Ventricular Ejection Fraction (LVEF) comparable with cardiac MRI.

Treadmill Test (TMT)/ Stress Testing

A treadmill test used diagnostically is considered to have a positive result if the patient develops signs and symptoms of ischemia during stress, i.e., ST-segment depression and angina. In stress testing, the heart is monitored by ECG and often imaging studies during an induced episode of increased cardiac demand so that ischemic areas potentially at risk of infarction can be identified. Heart rate is increased to 85% of age-predicted maximum (target heart rate) or until symptoms develop, whichever occurs first. Stress testing is used for diagnosis of Coronary Artery Disease (CAD) and for risk stratification and monitoring of patients with known CAD. Accuracy of stress test for diagnosis is very low especially with single vessel disease. Patient with strong positive TMT (more than 2 mm ST changes, hypotension, ST-T changes in multiple plane at low work load) must undergo coronary angiography as nature history of this patient is not good otherwise.

Stress testing is less invasive and less expensive than cardiac catheterization, and it detects path physiologic abnormalities of blood flow; however, it is less accurate for diagnosis in patients with a low pretest likelihood of CAD. Because coronary artery plaques that are not significantly stenotic (i.e., do not result in ischemia during stress testing) may nonetheless rupture and cause an acute coronary syndrome, a normal stress test result does not guarantee future freedom from MI. Risks of stress testing include infarction and sudden death, which occur in about 1 out of 5000 patients tested. Stress testing has several contraindications.

TMT is absolutely contraindicated in acute coronary

syndrome (MI within 48 h or uncontrolled unstable angina), aortic dissection (acute), aortic stenosis if symptomatic or severe, arrhythmias if symptomatic or hemodynamic ally significant and heart failure if decompensated .

Coronary angiography

Coronary angiography is gold standard for diagnosis of CAD. One can exclude CAD at the same time it can guide clinicians on management of this patients (Medical, CABG and Angioplasty). Coronary angiography through radial root is easily accepted by patients. It has less chance of heamatoma and the patient can be discharged within 2-3 hours. It has an advantage that one can have idea of collaterals.

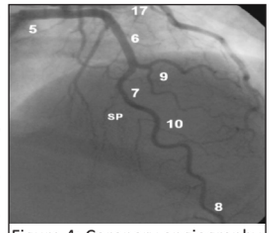


Figure 4: Coronary angiography

There are few pitfalls of coronary angiography like eccentric plaque, overlapping area and 100% occlusion.

7 Sec Angiography in which tube over heart rotates, so that only in one view whole left and in another view right coronary artery can be evaluated. It is very fast and requires less dye. It is very useful in patients with LV dysfunction and altered renal function.

7 second angiography feature is a recent addition to the cath lab launched world wide which is available at our center, CIMS.

Contraindications

Relative contraindications for cardiac catheterization include renal insufficiency, coagulopathy, fever, systemic infection, uncontrolled arrhythmia or hypertension and uncompensated heart failure.

Complication

Mortality rate is 0.1 to 0.2%. MI (0.1%) and stroke (0.1%) may result in significant morbidity. Other complications include allergic reaction- anaphylaxis and dye induced nephropathy in old age and diabetic patients.

Intravascular Ultrasound (IVUS)

Miniature ultrasound transducers on the end of coronary artery catheters can produce image of coronary vessel lumina and walls and delineate blood flow. This technique is useful along with coronary angiography. It gives better assessment of composition of plaques (Ca++), and stent expansion which determines long term outcome after angioplasty. Thus, it helps cardiologist to improve outcome of angioplasty.

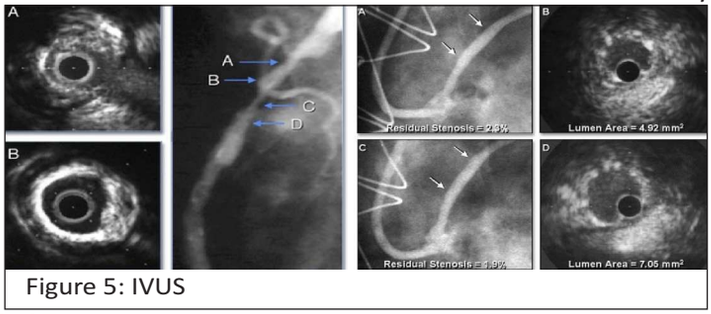


Figure 5: IVUS

Coronary Artery Flow Measurement

Extremely thin guidewires are available with pressure sensors or Doppler flow sensors. It can be useful to estimate coronary flow (expressed as Fraction Flow Rate). These flow measurements are most useful in intermediate lesions (40 % - 70% stenosis) with multiple lesions to identify those that are clinically significant.

Computed Tomography

Newer CT scans are of great help in measuring calcium score and CT angiography.

Coronary Artery Calcium Score

Calcium deposition along the coronary artery walls is a surrogate biomarker for atherosclerosis, and its presence in the coronary arteries could reflect the severity of CAD.. Coronary Artery Calcification (CAC) can be quantified with the use of cardiac CT and it is proportional to the extent and severity of atherosclerotic disease.

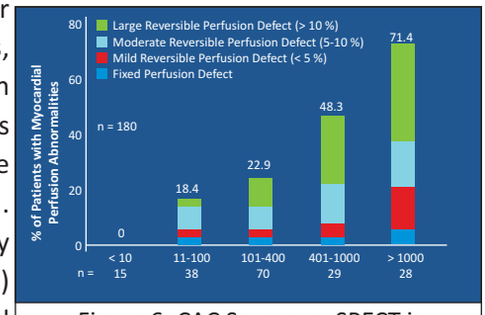


Figure 6: CAC Scores vs. SPECT in Asymptomatic Type 2 Diabetes

Agatston Score

Calcium score in major coronary arteries is expressed as an Agatston Score.

Agatston Score = Hounsfield Units X Area

Hounsfield Units:	
130-199	1
200-299	2
300-399	3
>400	4

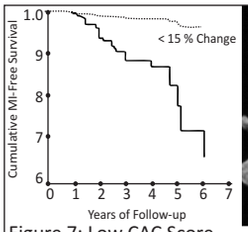


Figure 7: Low CAC Score indicates an excellent prognosis

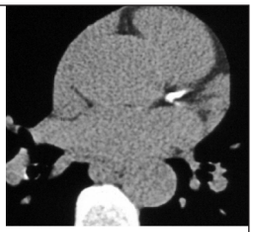


Figure 8: Calcium Score

Soft plaque of significant severity can be missed with CAC due to absence of calcium in it.

CT Angiography

Excellent feasibility and diagnostic accuracy make 64-slice MDCT a new useful imaging modality for the anatomic evaluation of coronary circulation. 64 slice MDCT has 98% sensitivity, 93% sensitivity, 74% positive predictive value, and 98% negative predictive value. The extremely high negative predictive value suggests its use to exclude coronary artery disease.

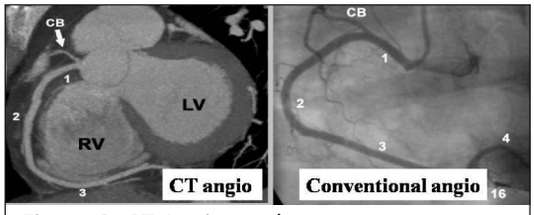


Figure 9: CT Angiography

CT angiography can be very useful in setting of acute chest pain in an emergency department as it can help to diagnose certain life threatening disease like pulmonary embolism, dissection of aorta along with CAD.

Radiation exposure during MDCT is about 15 mSv which is significant whereas it is 0.1 mSv for simple X-ray, 7.0 mSv for coronary angiography and 10-11 mSv for stress gated myocardial perfusion. Hence, MDCT technology improvisation is focused on reduction of the radiation dose.

Limitation of CT Angiography

i) Radiation exposure is much higher than coronary angiography
ii) Iodinated contrast agent induced nephrotoxicity
iii) CTA image quality depends on diastolic window (heart rate and R- R interval)
iv) Visualization of distal coronary artery segments is suboptimal in many patients
v) Coronary calcium obscures true lumenal diameter ("blooming effect")
vi) Estimation of severity of stenosis is problematic

Relative Contraindication

- Known coronary artery disease
- High probability of coronary artery disease, by clinical presentation and history
- High probability of high coronary calcium content by risk factors, age, and male sex , DM -- long standing

ECG Gated Magnetic Resonance Imaging

ECG gated MRI is helpful in assessing LV function, visualization of coronary tree and viability. Disadvantages of cardiac magnetic resonance include high cost and limited availability.

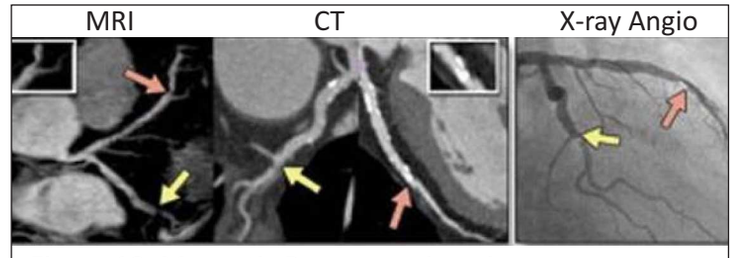


Figure 10: Magnetic Resonance Imaging

The entire acquisition and image processing can be time consuming (30 min or more on average). MRI cannot be used in patients with severe claustrophobia. It is also absolutely or relatively contraindicated in patients with pacemakers, defibrillators, certain aneurysm clips and other indwelling ferromagnetic materials. Newer pacemakers are MRI compatible. MRI is feasible only in cooperative patients.

Nuclear Imaging

Nuclear imaging using nuclear techniques has high sensitivity for tracer detection which can help to detect not only perfusion but also metabolism. Nuclear imaging techniques include single photon emission computed tomography and positron emission tomography.

Single-photon emission computed tomography (SPECT)

It is a very useful for both diagnosis and prognosis of patients with CAD. SPECT is more sensitive for detection of CAD than TMT. It involve radiation and is not available everywhere.

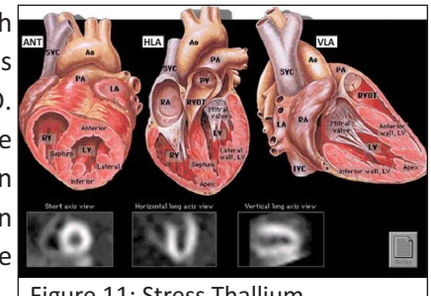


Figure 11: Stress Thallium

Positron Emission Tomography (PET)

Positron emission tomography is an accurate method to assess myocardial perfusion and metabolism in detection of coronary artery disease. Like SPECT, PET also uses exercise or dobutamine (or vasodilator) to induce stress. Three positron emitting radiotracers are used for cardiac PET namely 13N and 82Rb for evaluation of myocardial perfusion and 18F deoxy-D-glucose (FDG) for assessing myocardial glucose metabolism.

The use of PET in assessing myocardial perfusion is expected to increase in near future with emergence of low cost PET systems and regional distribution of positron emitting radiotracers. A meta-analysis has showed better sensitivity and specificity of PET for the diagnosis of coronary artery disease with 92% and 85%, respectively which is higher compared to stress thallium. Image quality (artifact free image) and accuracy of PET is better compared to SPECT.

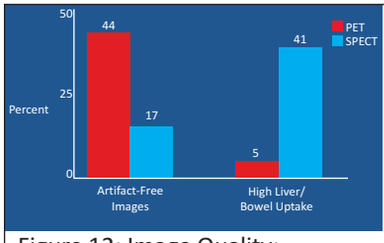


Figure 12: Image Quality: Comparison of PET With SPECT

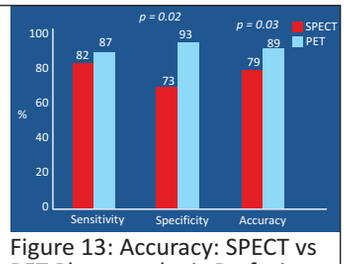


Figure 13: Accuracy: SPECT vs PET Pharmacologic Perfusion Imaging

PET with FDG evaluates atherosclerotic plaques.

The disadvantages of PET including high cost, availability of technique and expert person which hinder the use of PET for myocardial perfusion.

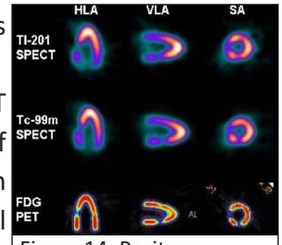


Figure 14: Positron Emission Tomography

Viability:

Before subjecting patient to high risk CABG it is better to know viability so that high risk CABG can be avoided.

Thallium kinetics are directly proportional to tissue blood flow.

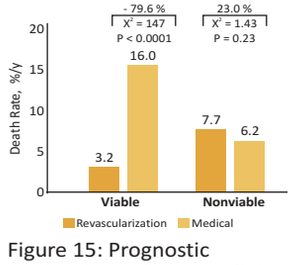


Figure 15: Prognostic Implications of Myocardial Viability Testing

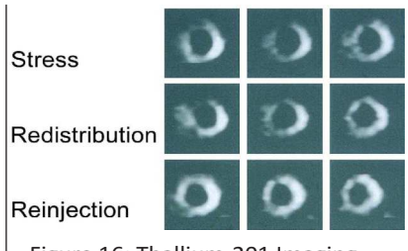


Figure 16: Thallium-201 Imaging for Myocardial Viability

Hence, normal tissue has more rapid uptake and washout than underperfused, viable tissue. Thallium redistribution in regions that initially had a thallium defect is the hallmark of viability by this technique. Thallium reinjection after stress or 3- to 4-hour redistribution imaging significantly improves viability assessment, as does semiquantitation of thallium activity.

As one can detect perfusion and metabolism with PET, it is very useful tool for assessing myocardial viability. It is more accurate than stress thallium.

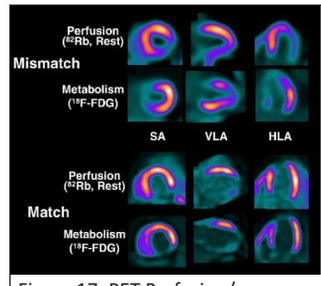


Figure 17: PET Perfusion/ Metabolism Imaging for Assessment of Myocardial Viability

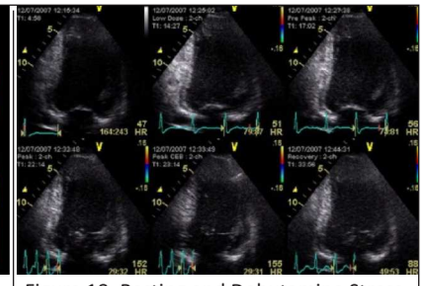
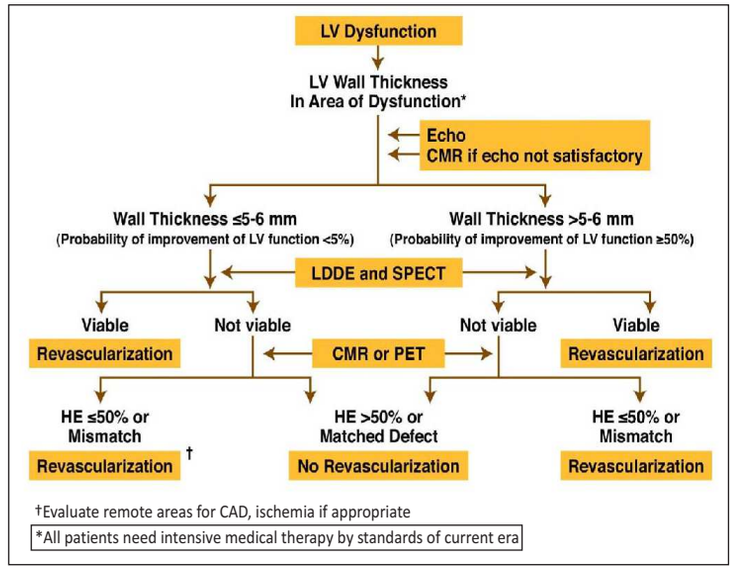


Figure 18: Resting and Dobutamine Stress Echo for Myocardial Thinning, CR, and Myocardial Ischemia low dose

Positive Predictive Value (PPV) of nuclear imaging is higher than dobutamine echocardiography and Negative Predictive Value (NPV) of dobutamine echocardiography is higher compared to nuclear imaging.



Conclusion

The availability of multiple techniques presents the clinician with the challenge of knowing the relative utility of each method in order to choose the appropriate technique(s) for each clinical setting. Available tests all have advantages and drawbacks, and none can be considered suitable for all patients. The information obtained from tests should be accurate, reliable and reproducible. It should also provide incremental prognostic value to the risk predicted by clinical assessment. Merits and demerits discussed in the article are helpful for clinicians to decide appropriate technique.

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