Which Imaging Study for Which Condition?

DON'T TEST

Treadmill stress test

Stress Echo

PET

CCTA

SPECT

CAC

CMR

TEE

Treadmill stress test
When to start with Echo

To assess symptoms, chamber size, wall thickness, effusion, cardiac function
When to start with Echo

Murmur, valve disease, masses
Growth in Advanced Imaging Utilization Services, Including CT, MR, and PET
## Typical radiation doses

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Radiation Dose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stress echo</td>
<td>0 mSv</td>
</tr>
<tr>
<td>CMR</td>
<td>0 mSv</td>
</tr>
<tr>
<td>CXR</td>
<td>0.05 mSv</td>
</tr>
<tr>
<td>Coronary calcium score</td>
<td>1-2 mSv</td>
</tr>
<tr>
<td>Coronary CTA</td>
<td>4-8 mSv</td>
</tr>
<tr>
<td>PET</td>
<td>4-8 mSv</td>
</tr>
<tr>
<td>Cardiac cath</td>
<td>4-10 mSv</td>
</tr>
<tr>
<td>Chest CTA (R/O PE)</td>
<td>10-20 mSv</td>
</tr>
<tr>
<td>Abdominal/pelvic CT</td>
<td>15-20 mSv</td>
</tr>
<tr>
<td>SPECT (Tc-99m)</td>
<td>11-14 mSv</td>
</tr>
<tr>
<td>SPECT (Thallium)</td>
<td>20-26 mSv</td>
</tr>
</tbody>
</table>
Growth in services for Medicare beneficiaries

Strategies against “Imaging Epidemic”

- Cut reimbursement
- Change reimbursement model
- Mandate pre-authorization
- Appropriate Use Criteria (AUC)
- Incorporate specialty consultation
### Appropriate Use Criteria (AUC)

**Multi-Modality AUC**

**Symptomatic Patients**

<table>
<thead>
<tr>
<th>Indication Text</th>
<th>Ex ECG</th>
<th>Stress RNI</th>
<th>Stress Echo</th>
<th>Stress CMR</th>
<th>Ca Scoring</th>
<th>CCTA</th>
<th>DX Cath</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Low pre-test prob of CAD - ECG interpretable AND able to exercise</td>
<td>A</td>
<td>R</td>
<td>M</td>
<td>R</td>
<td>R</td>
<td>R</td>
<td>R</td>
</tr>
<tr>
<td>2. Low pre-test prob of CAD - ECG uninterpretable OR unable to exercise</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>M</td>
<td>R</td>
<td>M</td>
<td>R</td>
</tr>
<tr>
<td>3. Interm pre-test prob of CAD - ECG interpretable AND able to exercise</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>M</td>
<td>R</td>
<td>M</td>
<td>R</td>
</tr>
<tr>
<td>4. Interm pre-test prob of CAD - ECG uninterpretable OR unable to exercise</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>R</td>
<td>A</td>
<td>M</td>
</tr>
<tr>
<td>5. High pre-test prob of CAD - ECG interpretable AND able to exercise</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>R</td>
<td>M</td>
<td>A</td>
</tr>
<tr>
<td>6. High pre-test prob of CAD - ECG uninterpretable OR unable to exercise</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>R</td>
<td>M</td>
<td>A</td>
</tr>
</tbody>
</table>

*J Am Coll Cardiol 2014*
SCREENING for coronary disease

American College of Physicians 2015

- No evidence that cardiac screening improves outcomes
- In low risk adults, prevalence of coronary heart disease is low
- Emphasize strategies to reduce cardiovascular risk
- (Recommendations do not apply to symptomatic patients or to screening athletes before participation in various events.)
Imaging for **symptoms** and signs of suspected CORONARY DISEASE

- Exercise ECG Test (ETT)
- Nuclear stress perfusion scan (MPI, SPECT, PET)
- Coronary CT angiography (CCTA, CTA)
- Coronary calcium scan (CAC, EBCT)
- Stress echo
Exercise ECG

Initial test for majority of patients who can exercise adequately, have an interpretable ECG, without certain ECG conditions (eg, left bundle branch block, paced ventricular rhythm, ventricular pre-excitation, etc).

*Duke Treadmill Score* to stratify into low, intermediate, and high-risk

\[
DTS = \text{Exercise time} - (5 \times \text{ST deviation}) - (4 \times \text{chest pain [0=none, 1=nonlimiting, 2=limiting]})
\]

Low risk= 5 to 15 , Moderate risk= -9 to 4  High risk= ≤ -10

Age is strong prognostic predictor: >10-fold difference in CV mortality for similar DTS among 4 age decades

When to do imaging stress testing:

Intermediate or high pretest probability of CHD: stress imaging has higher sensitivity and specificity for diagnosis of obstructive CHD.

Known CHD: either radionuclide myocardial perfusion or stress echo to localize and quantify ischemia

CHD + prior MI : to assess myocardial viability, MPI with PET or CMR
Inconclusive exercise treadmill test

Equivocal ETT

What is the goal of further testing?
- Identify amount of ischemia
- Assess need for revascularization

What is the risk of obstructive CAD?
- High risk
- Low to intermediate risk

Need for further testing?
- High exercise capacity (e.g., >13 METs)
- Asymptomatic
- Low clinical risk profile
- No testing

Nuclear MPI
Cardiac MRI
Stress echocardiogram

Need to evaluate non-coronary structures; no radiation preferred

Cardiac MRI or Stress echocardiogram

Obese patients
Myocardial blood flow quantification desired

SPECT
PET
Coronary computed tomography angiography (CCTA)

- High negative-predictive value of CCTA identifies patients unlikely to have obstructive CAD

- Requires normal kidney function (e.g., creatinine ≤1.5 mg/dL) and low resting heart rate, often achieved by pre-scan treatment with β-blockers

- Increased use of CCTA has led to patient radiation dose concerns

- Poor positive-predictive value for the detection of ischemia.

In asymptomatic patients with type 1 or type 2 diabetes, CCTA to screen for CAD did not reduce composite rate of all-cause mortality, nonfatal MI, or unstable angina

-- Muhlestein JB et al, Factor-64 Study, JAMA December 3, 2014
Coronary artery calcium (CAC)

Can be performed rapidly during a single breathhold, is relatively inexpensive, and does not require any intravenous contrast.

Strong relationship between severity of CAC and risk of future cardiovascular events—patients with severe CAC (e.g. 9300) have a nearly 6-10-fold increased risk of adverse coronary events.

Absence of CAC is associated with excellent long-term prognosis in both asymptomatic (event rate 0.6% over mean follow-up of 4 years) and selected symptomatic (event rate 1.8% over mean follow-up of 3.5 years) patients.

CAC in symptomatic patients is controversial, as some patients with no CAC may have obstructive disease from noncalcified plaque.

A strategy of primarily CAC (followed by CTA only if CAC was between 1 and 400; or invasive angiography if CAC>400) resulted in a sensitivity of 88% and a negative predictive value of 98% for excluding obstructive CAD.

CAC cannot be used to determine whether obstructive CAD is present or absent.
Nuclear myocardial perfusion imaging (MPI)

used to detect flow-limiting CAD -- ischemia

SPECT, single photon emission computed tomography
PET MPI

In comparison to SPECT, PET MPI has superior spatial resolution, better attenuation correction, and higher diagnostic accuracy. Rapid half-life of radiotracers in PET results in lower radiation dose and faster protocol.

Improved diagnostic accuracy, less artifacts
Fewer false positives
Much shorter – 30 minutes
Less radiation
Viability testing
Quantitative blood flow measurements
PET/CT: With calcium score

Obese patients
Equivocal prior stress test
Negative prior stress test + recurrent symptoms
Procedural planning in CAD
Detect microvascular CAD
Disadvantage: only vasodilator, not exercise
Stress echocardiography

• similar accuracy vs. nuclear perfusion imaging for detection of obstructive CAD

• perfusion imaging may be more sensitive for detection of mild CAD, stress echocardiography has better specificity for excluding CAD

• stress echocardiography can also be used to evaluate exercise induced dyspnea in patients with valvular heart disease or suspected exercise-induced heart failure with preserved ejection fraction and/or pulmonary hypertension

• Echocardiography has the benefit of widespread availability and absence of radiation
Non-invasive Imaging in the Work-Up of Cardiomyopathies

Signs and symptoms suggestive of cardiomyopathy

**TTE** for evaluation of cardiac structure and function

Structural or functional cardiac abnormality

Evaluate for ischemic or nonischemic etiology

Stress test with imaging

CCTA

CMR

Consider invasive x-ray angiography

Structural or functional cardiac abnormality

Consider additional imaging (TEE, Mull, CMR, CCTA) if TTE technically limited

Technically limited or no cardiac abnormality

Yes cardiac abnormality

Evaluate for non-cardiac causes

Non-ischemic Cardiomyopathy

Consider etiology based on history and imaging phenotype

Secondary causes

Hypertensive heart disease

Valvular heart disease

Congenital heart disease

DCM

HCM

RCM

ARVC

Unclassified

Consider additional imaging (TEE, CMR, CCTA) to evaluate underlying secondary cause

Treatment focused on underlying secondary cause

Ischemic Cardiomyopathy

Optimize medical therapy

Consider imaging for viability and prognosis

Significant ischemia and/or viability

Revascularization

Continue optimal medical therapy

No significant viability

Follow-up or serial imaging to monitor disease progression

Follow-up or serial imaging to monitor disease progression

Consider ICD and/or CRT

Consider ICD and/or CRT
Cardiac magnetic resonance imaging (CMR)

- high-resolution imaging of cardiac structure, function, and morphology
- no radiation exposure
- advantageous in patients who also require an evaluation for other suspected cardiac conditions.
- high-contrast resolution for myocardial characterization, in evaluating known or suspected infiltrative heart disease or cardiac masses
- superior sensitivity (86% vs 74%) and specificity (86% vs 70%) of cardiac MRI over stress echocardiography for detecting stress-induced wall motion abnormalities
- echocardiography has better spatial and temporal resolution and therefore may be more robust for evaluating small, highly mobile structures such as small vegetations.
- CMR sequences are dependent on ECG gating and require breath-holding, and thus image quality may be reduced in patients with highly irregular heart rhythms
- Cardiac MRI is a complex exam that is currently limited by lack of availability and high cost. This test cannot be performed in patients who are claustrophobic or who have implanted ferromagnetic objects
Cardiac MRI in Amyloidosis
CMR in Arrhythmogenic Right Ventricular Cardiomyopathy/Dysplasia (ARVC/ARVD)
Arrhythmogenic Right Ventricular Cardiomyopathy

3D echocardiography, apical view in a patient with ARVD/C:
Enlarged globally hypokinetic RV.
The apex is significantly dilated, with trabecular prominence. The video demonstrates severe global RV dysfunction with akinesia of the RV apex and prominent trabeculae.
Diagnostic Workup in Patients with Potential Cardiac Sources of Emboli

Echocardiography = primary form of cardiac imaging
-- supplemented by chest xray, computed tomography (CT), magnetic resonance imaging (MRI), and nuclear imaging when necessary.

2D High-Frequency and Fundamental Imaging
Three-Dimensional and Multiplane Imaging
Saline and Transpulmonary Contrast
Color Doppler
TTE and TEE
Atrial Fibrillation

3D TEE
SUMMARY Recommendations

1. Use **History** -- assess **pre-test probability** to minimize false positives

2. Consider cost, **false-positive** rates in cardiac imaging

3. Minimize **radiation** exposure: Echo < PET < CT < SPECT

4. Rarely perform stress testing / screening in **asymptomatic** patients

5. For **preoperative** assessments, patients with ability > 4 METs do not require testing, regardless of type of surgery or risk profile.

6. Understand the **ischemic cascade**: stress echo for greater specificity (lower false positive), nuclear perfusion for greater sensitivity

7. CCTA reasonable for patients unable to do exercise, pharmacologic nuclear or stress echo, with low to intermediate pretest probability of CAD.