Cardiovascular Imaging: Ordering the right test for the right patient: a potpourri of CV Imaging pearls

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Medical Director Advanced Cardiovascular Imaging

Franciscan HEALTH
Disclosures

- I have no relevant financial relationships to disclose
- I will be discussing off label use of gadolinium contrast agents for CV MRI.
- The pictures are not of real patients and the cases are fictitious
Educational Objectives

- Understand the role of Calcium scoring in the care of patients
- Understand the strengths, weakness and trade offs of CV Imaging modalities
- Learn to employ multi-modality imaging to answer complex clinic questions
- Order stress testing like a pro
Other Disclosures
Case #1

- 62 yo female executive 0.5 ppd smoker for 10 years, but quit 6 months ago with htn treated with lisonopril, and has a LDL of 150mg/dL, HDL 38

- "Am I going to have a heart attack like Mom?"

- FRS: 7.5%-10 year
“Heads, you get a quadruple bypass. Tails, you take a baby aspirin.”
Pick the Next best test

a) Re-assurance, diet, exercise
b) Start her on moderate intensity statin
c) Coronary Artery Calcium Score
d) hs-CRP and CIMT
e) Exercise ECG
f) CCTA
Pick the Next best test

a) Reassurance, diet and exercise
b) Start her on Medium intensity statin—maybe
c) Coronary Artery Calcium Score
d) hs-CRP and CIMT
e) Exercise ECG
f) CCTA
Uses of Coronary Calcium Scoring

- Use a calcium score to screen patients with moderate (intermediate) Framingham risk
  - Positive CAC scans indicate incremental risk
  - May alter therapeutic goal (Life-style vs meds)
- Identify patients who do not need further cardiac evaluation - the Power of ZERO
- Improve compliance
- Powerful tool for prognosis and risk stratification
This is Much different

<table>
<thead>
<tr>
<th>Score</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>#ROI's</td>
<td>0</td>
</tr>
<tr>
<td>eaSq (sq.mm.)</td>
<td>0</td>
</tr>
</tbody>
</table>
...from this
Things to know about Calcium scoring

- Low-dose 1-1.5mSv Screen Chest CT to quantify how much calcified plaque someone has
- Plaque formation is NOT a part of natural aging
- Not covered by insurance, cost $49 out-of-pocket
- CAC scores detect Calcified plaque NOT stenosis
- CAC score of ZERO gives most patients a 10y warrantee! (James Min JACC aug 2015)
- Consider CAC score for 5-20% risk (Low to Intermediate) on Framingham/ASCVD Pooled risk cohort
- Higher the score, higher the risk:

Scores:
- Zero: Very low risk
- 1-100 Low risk
- 101-299 Intermediate risk
- >300 = CAD risk equivalent

- If >75th percentile, Intermediate risk
- If >90th% then High risk, CAD equivalent
- If CAC score ZERO, consider de-escalation of meds.
  *Some Expert opinion*

- MESA-NHLBI.org Risk Calculator
Calcium scoring will MISS Non-calcified plaque. Obstructive disease may still be present in score of zero; rare but possible.

Use in ASYMPTOMATIC people only... NOT a substitute for functional testing or CATH.
Don’t order a CAC score in these patients

- People unlikely to live 1 year
- Known CAD, past PCI or Bypass
- Is pregnant or potentially pregnant
- Recent CAC score in past 5 years
- Low risk, <5% 10 year risk, unless Family hx
Or these people

- History of PAD, PVD such as AAA, carotid disease, etc..
- Very high risk patients >20% 10 year risk
Consider CAD scoring in

- Age 40-80 with 5-20% Framingham / ASCVD 10 year risk
- 2 more major risk factors:
  - DM1 or DM2
  - Cigarette smoker or significant smoking hx
  - Low HDL
  - Htn
  - Fem hx of CAD
Other Non-traditional risk factors

- Metabolic syndrome
- Increased Waist-to-Height ratio >0.5
- Chronic Kidney disease
- Rheumatologic disease (SLE, RA)
- HIV on HAART (lipodystrophy)
- Atherogenic dyslipidemia TAG/HDL ratio >3:1
Powerful tool for Prognosis

\[ \chi^2 = 1503, p < 0.0001, \text{ interaction } p < 0.0001 \]
The power of CAC scoring over the next 15 years!

<table>
<thead>
<tr>
<th>CAC score</th>
<th>Overall mortality</th>
<th>Relative hazard for all-cause death (p-value)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>3%</td>
<td>--</td>
</tr>
<tr>
<td>1-10</td>
<td>6%</td>
<td>1.68 (p &lt; 0.001)</td>
</tr>
<tr>
<td>11-100</td>
<td>9%</td>
<td>2.91 (p &lt; 0.001)</td>
</tr>
<tr>
<td>101-399</td>
<td>14%</td>
<td>4.52 (p &lt; 0.001)</td>
</tr>
<tr>
<td>400-999</td>
<td>21%</td>
<td>5.53 (p &lt; 0.001)</td>
</tr>
<tr>
<td>≥ 1,000</td>
<td>28%</td>
<td>6.26 (p &lt; 0.001)</td>
</tr>
</tbody>
</table>

- Direct costs of poor adherence
  $100-289b Annually
- Up to 80% of CVD could be prevented by eliminating obesity, unhealthy diets and physical inactivity.
Calcium scoring may lead to improved adherence

- Improved risk factor profile (EISNER)
- Intensification of Medical regimen (MESA)
- Adherence to meds (Kalia et al. Atherosclerosis. 2006)
- Increased physical activity
Calcium predicts events better than CRP

CHD Event Rates (Per 1,000 Person-Years)
Event rates are according to C-reactive protein (CRP) and coronary artery calcium (CAC) levels among those with low-density lipoprotein <130 mg/dl. CHD = coronary heart disease.
Using CAC scoring to GUIDE STATIN USE?

Estimated 5-Year Number Needed to Treat (NNT<sub>5</sub>) to Prevent One CHD or CVD Event, by Coronary Artery Calcium (CAC) Burden

<table>
<thead>
<tr>
<th>JUPITER-eligible population</th>
<th>Estimated CHD event rate at 5.8 years</th>
<th>Estimated CVD event rate at 5.8 years</th>
<th>5-year NNT for CHD</th>
<th>5-year NNT for CVD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zero CAC</td>
<td>0.48%</td>
<td>2.12%</td>
<td>549</td>
<td>124</td>
</tr>
<tr>
<td>CAC present</td>
<td>6.22%</td>
<td>8.87%</td>
<td>42</td>
<td>30</td>
</tr>
<tr>
<td>CAC=0</td>
<td>0.48%</td>
<td>2.12%</td>
<td>549</td>
<td>124</td>
</tr>
<tr>
<td>CAC 1–100</td>
<td>2.79%</td>
<td>4.86%</td>
<td>94</td>
<td>54</td>
</tr>
<tr>
<td>CAC &gt;100</td>
<td>10.76%</td>
<td>13.65%</td>
<td>24</td>
<td>19</td>
</tr>
</tbody>
</table>
Calcium Score predicts ASA benefit in MESA

2014;7:453-460
Stress testing
Hey Doc, I have this sharp, stabbing chest pain...
If you loosen the belt a little, you won’t get those horrible chest pains..
The Ischemic Cascade

Oliver Gaemperli et al. Eur Heart J. 2013;34:2432-2435
<table>
<thead>
<tr>
<th>Test</th>
<th>Diagnosis of CAD</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Sensitivity (%)</td>
</tr>
<tr>
<td>Exercise ECG</td>
<td>45–50</td>
</tr>
<tr>
<td>Exercise stress echocardiography</td>
<td>80–85</td>
</tr>
<tr>
<td>Exercise stress SPECT</td>
<td>73–92</td>
</tr>
<tr>
<td>Dobutamine stress echocardiography</td>
<td>79–83</td>
</tr>
<tr>
<td>Dobutamine stress MRI</td>
<td>79–88</td>
</tr>
<tr>
<td>Vasodilator stress echocardiography</td>
<td>72–79</td>
</tr>
<tr>
<td>Vasodilator stress SPECT</td>
<td>90–91</td>
</tr>
<tr>
<td>Vasodilator stress MRI</td>
<td>67–94</td>
</tr>
<tr>
<td>Coronary CTA</td>
<td>95–99</td>
</tr>
<tr>
<td>Vasodilator stress PET</td>
<td>81–97</td>
</tr>
</tbody>
</table>

CAD = coronary artery disease; CTA = computed tomography angiography; ECG = electrocardiogram; MRI = magnetic resonance imaging; PET = positron emission tomography; SPECT = single photon emission computed tomography.

* Results without/with minimal referral bias.

* Results obtained in populations with medium-to-high prevalence of disease without compensation for referral bias.

* Results obtained in populations with low-to-medium prevalence of disease.
<table>
<thead>
<tr>
<th>Stress Modalities</th>
<th>Imaging Modalities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exercise</td>
<td>ECHO</td>
</tr>
<tr>
<td>Pharmacologic</td>
<td>SPECT</td>
</tr>
<tr>
<td>Dobutamine</td>
<td>PET</td>
</tr>
<tr>
<td>Adenosine</td>
<td>MRI</td>
</tr>
<tr>
<td>Persantine</td>
<td>CT</td>
</tr>
<tr>
<td>Regadenason</td>
<td></td>
</tr>
</tbody>
</table>
Stress test

Can they exercise*?

Yes

Is the ECG normal?

Yes

Known CAD or high pre-test?

No

Exercise ecg

No

Pharmacologic Stress

Yes

Imaging
10 Tips for ordering stress testing

- If they can exercise, Exercise
- Use imaging if ECG uninterpretable, patient can't exercise or if increased pre-test probability of CAD
- Use vasodilator stress in patients with a LBBB, e.g. regadenson, adenosine, etc
- Stress echo better in lower pretest
- Nuclear better for peri-infarct ischemia
Stress testing Pearls

- Avoid use of dobutamine as stress agent in afib.
- Use of anti-anginals nitrates, CCB, Beta-blockers will reduce sensitivity of imaging - they work
- Caffeine needs be avoided prior to pharm stress (reduces effectiveness of vasodilation)
- If someone is on a beta-blocker, increased likelihood of a nondiagnostic treadmill.
- BP needs to be under reasonable control - less than 180/100 - prior to testing or risk of false +
More pearls

- Cardiac PET (quantitatively) and Stress MRI (qualitatively) can detect microvascular ischemia
- Avoid vasodilator stress in patients with active wheezing
- Please don’t stress high pre-test patients with classical angina.
- GI distress, dyspnea and chest pain may occur with vasodilator stress
#WHYCMR

- Gold standard for functional and volumes, both left and right sided. (ICD eval, prognosis in pulm htn, timing of valve surgery)
- Tissue characterization: edema, scar burden, fibrosis, iron content
- Why does my patient have HFREF or HFPEF?
- Viability
- Why is the heart thick? LVH, HCM or infiltration
- Cardio-oncology
#WHYCMR

- Flow quantification
- Ischemia Eval (Stress MRI)
- Causes of arrhythmia (ARVC, Scar, myocarditis, infiltration)
- Consider for poor quality Echos
- Congenital heart disease
PATIENT SELECTION

- Test takes from over 30 minutes to over an hour
- Need to be able to hold still, FLAT, and hold breath repeatedly
- eGFR >30
- Hemodynamically stable please
- Coughing, short of breath patients, or can’t follow commands, are poor choices (unless intubated)
- Coronary stents are ok, as are most heart valves (even mechanical ones) - check device safety
Strengths of Cardiac MRI

<table>
<thead>
<tr>
<th></th>
<th>Morphology</th>
<th>Function</th>
<th>Tissue</th>
<th>Metabolism</th>
</tr>
</thead>
<tbody>
<tr>
<td>Echo</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nuclear</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CT</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CMR</td>
<td></td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>
Indications

- Normal Cardiac and Vessel Anatomy
- LV Volumes, Mass, EF and regional function
- Size and function of RV
- Atria and Pulmonary Veins
- Valvular Heart Disease
Indications

- Myocardial Mass
- Pericardial Disease
- Dilated Cardiomyopathies
- Hypertrophic Cardiomyopathies
- Iron Cardiomyopathy
- Myocarditis
Indications

- Simple Congenital Heart Disease
- Complex Congenital Heart Disease
- Stress MRI
- Delayed Enhancement (Viability)
- Angiography
- Coronary anomalies
Tissue Characterization

Diastole

Systole

Lack of edema

Scar
Myocardial Edema
Evaluation for type of Cardiomyopathy
Replacement scarring
T2* or Iron Imaging
4D flow images pending
SPECT MPI

- Uses radiation
- More expensive than Echo
- Lacks spatial resolution of PET, but better at peri-infarct ischemia than Echo
- Suffers from problems with soft-tissue attenuation as well.
SPECT Limitations

- False negatives in “Balanced ischemia or 3vd”
- False negatives in women “Small hearts”
- False positives in the Obese, or with large breasts
SPECT (Nuclear MPI)

Uses:
- technitium labeled sestamibi
- “a MIBI” or Cardiolyte®
- or tetrofosmin “a Myoview”.
Stress Echo Limitations

- Sound waves attenuate with distance
- Poor (technically difficult) pictures in
  - Obese
  - Severe COPD
- In setting of prior MI, poor sensitivity in detecting peri-infarct ischemia
- Poor “windows”
Echocardiography

- Inexpensive
- Doesn’t use radiation
- Readily accessible
- Good sensitivity, fair specificity
### Pros and CONSs

<table>
<thead>
<tr>
<th>Test</th>
<th>COST</th>
<th>Radiation</th>
<th>Accuracy</th>
<th>Don’t use in:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Echo</td>
<td>$</td>
<td>NO</td>
<td>80%</td>
<td>Bad windows</td>
</tr>
<tr>
<td>SPECT</td>
<td>$$$</td>
<td>yes</td>
<td>80%</td>
<td>Morbidly obese</td>
</tr>
<tr>
<td>PET</td>
<td>$$$</td>
<td>yes</td>
<td>90-95%</td>
<td></td>
</tr>
<tr>
<td>CT</td>
<td>$$$</td>
<td>yes</td>
<td>High NPV</td>
<td>Renal insuff. Known CAD</td>
</tr>
<tr>
<td>MRI</td>
<td>$$$$</td>
<td>NO</td>
<td>80%</td>
<td>Metal</td>
</tr>
</tbody>
</table>
Cardiac CTA

- Uses radiation
- More expensive than Echo
- Outstanding Negative predictive value (High 90%) or “Does my patient have CAD?”
- Fair at assessing degree of obstruction or “Is that blockage causing ischemia (or chest pain)”?
Great test for the following Patients

- Symptomatic patients with low-intermediate Framingham risk
- Equivocal stress test
- Acute CP in the ED
- Suspected anomalous Coronaries
Coronary Cardiac CTA

- Difficult to get pre-approved, sometimes weeks.
- Can demonstrate other causes of chest pain, PE, Dissection, hiatal hernia, mass, PNA, PE, broken ribs....
- Great in assessing coronary anomalies
Not so great in these patients

- Significant Obesity, BMI >40
- Prior Coronary stents
- AKI or eGFR <30
- Contrast allergy
- Very irregular heart rhythm, AFIB
- Calcium score >600
“Warranty period” of Normal Cadiac CT extends to 7 years
For a minute there,
You bored me to death.
Case #2

48 yo male diabetic
with LBBB on ecg, Stage III CKD Cr 2.5, hypertension with fatigue and pleurtic chest pain
You should order

a) Exercise Echo
b) Vasodilator SPECT or PET
c) Cardiac catheterization
d) Cardiac CTA
e) Exercise SPECT MPI
You should order

a) Exercise Echo
b) Vasodilator SPECT
c) Cardiac catheterization
d) Cardiac CTA
e) Exercise SPECT MPI
Case #3

42 yo male with normal ecg, family history of CAD, horrible DJD and morbid obesity BMI 43, has chest pain that may be or may not be exertional.
You should order

a) Exercise Echo
b) 2 Day Pharm NM SPECT
c) Cardiac catheterization
d) Cardiac CT
e) Exercise Myoview
You should order

a) Exercise Echo
b) 2 Day Pharm NM SPECT or PET (PET preferred)
c) Cardiac catheterization
d) Cardiac CT
e) Exercise SPECT Myoview
Case #3
Vasodilator PET
PET is better in obesity
Case #4

- 42 yo female diabetic, smoker with history of asthma with dyspnea and pleuritic chest pain.
You should order

a) Exercise Echo
b) Cardiac catheterization
c) Cardiac CTA
d) Pharm SPECT MPI
You should order

a) Exercise Echo
b) Cardiac catheterization
d) Cardiac CTA
e) Pharm SPECT Myoview
Case #4

- Exercise echo
- Cardiac CT also reasonable
- Higher false positive nuclear in women
- Radiation risks
Case #5

- 75 yo male diabetic with LVH on ECG, atypical cp. History of chronic afib. On diltiazem and dig. Also has a h/o asthma/COPD, not actively wheezing.
You should order

a) Exercise Echo
b) Cardiac catheterization
c) Cardiac CTA
e) Adenosine Nuclear MPI (SPECT or PET)
F) Regadenoson Nuclear MPI
Regadenoson SPECT or PET,
- Not MRI, CT or echo.
- atrial fibrillation (afib) and calcium channel blockers (ccb) don't mix well with dobutamine.
- Avoid persantine and adenosine given COPD
Case #7

19 yo college man with exertional chest pain, fam h/o SCD. You sent him to exercise ecg which shows 2mm of ST depression at peak exertion.
You should order

a) Exercise Echo
b) Regadenoson PET
c) Cardiac catheterization
d) Cardiac CTA
e) Exercise SPECT Myoview
Case #7

Cardiac CT to check for anomalous coronaries;
Also could consider Cardiac MRI
Coming to Indianapolis airport

"We’re very thorough at this airport."
Physician’s guide to interpreting calcium scores is in your packet
References

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- Framinghamheartstudy.org
- MESA-NHLBI.org
- Ho Circulation 2009;19 3028-35
- Kalia et al. Atherosclerosis. 2006
- European Heart Journal (2013) 34; 2949-3000 doc 10.1093 surheartj/eht296