Stress MRI versus SPECT MPI, which is more cost effective?

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Objectives

• Understand basic principles behind cost effectiveness analysis

• Appreciate the factors that determine which modality will be more cost effective

• Be aware of the current cost effectiveness literature regarding imaging modalities in chronic stable ischemic heart disease
Economic Analysis

• When considering which healthcare technology represents better value for money, the first question to ask is what the money trying to buy

• Stated differently, what is the purpose of any healthcare intervention?

• Ultimately it boils down to two things. Improving the patient’s quantity and quality of life. The natural corollary to combating morbidity and mortality
The purpose of a diagnostic test is ultimately to improve the longevity and/or quality of life (improve outcomes).

That the diagnostic test does not attain this goal directly does not absolve it (or us) of the responsibility for achieving this goal and, increasingly, of a demonstration that this goal has been achieved.

Intermediate goals (plaque volume, LV EF, myocardial mass) are only worth achieving if it can be consistently demonstrated that they are linked to the final goals.
Quality Associated Life Year (QALY) – the currency of the final outcome

Measure of the survival benefit and the improved health state secondary to an intervention.

Health state is known as a utility. Perfect health is given a utility of 1 and death a utility of 0.

QALYs are transitive (meaning you can add them both between individuals and within individuals). Thus, an intervention which leads to 5 year survival in perfect health yields the same health benefit as 10 years in a health state accorded with a utility of 0.5
Health states in ischemic heart disease
Recall the COURAGE trial

Although PCI did not improve the longevity compared to optimal medical treatment it did improve the angina-free period and thus led to more QALYs
What is a cost effective technology?

A more effective technology is one which produces more QALYs.

If stress MRI is more effective than SPECT and cheaper, it dominates SPECT (win-win situation).

If stress MRI is less effective than SPECT and more expensive, it is dominated by SPECT (lose-lose situation).

If stress MRI is more effective than SPECT and more expensive, then its adoption depends on the willingness to pay for one additional QALY.
Willingness to pay (WTP)

How much is society willing to pay for one additional QALY?

Don’t consider costs at all (comparative effectiveness)

Reference case (dialysis costs $50,000 per QALY)
The key points

“Technology A is cost effective” can have different interpretations.

- Technology A produces an additional QALY at an acceptable additional cost - i.e. < $50,000 (ICER)
- Technology A dominates status quo (no diagnostic testing or an alternative modality)

**Incremental cost effectiveness ratio** is the important figure to ask because it determines the marginal cost. How much more is this new technology offering and at what additional cost? Flat of the curve or the upslope
How is cost effectiveness analysis performed?

1. **Alongside a clinical trial**
   Contrived, may not be generalizable

2. **Using decision modeling**
   - Data from disparate sources
   - A model for clinical decision-making
   - A model (Markov) for lifetime projection of the consequences of the initial decision
   - assumptions, assumptions, assumptions
   - aggregates, aggregates, aggregates
Suspected disease

- Test done
  - Diagnostic
    - Disease +
      - True positive
    - Disease -
      - False positive
      - True negative
  - Non diagnostic
- Test not done

Heller, Acad Rad, 1980
“All models are wrong...some are useful”
George Box

50 % pre-test probability (Diamond and Forrester, NEJM, 1979)
- 55 male atypical chest pain no risk factors
- 65 male with non-specific chest pain and no risk factor

(Assume the base case has no co-morbidities such as renal failure and has no arrhythmia)
- Consider fatal and non fatal complications of CCA
- Positive test – revascularization considered according to disease severity. Based on large registry (CASS) 97% of left main/triple vessel disease get CABG; 80% of two vessel disease and 50% of one vessel disease have angioplasty
What makes an effective imaging modality?

Diagnostic accuracy is necessary not sufficient

- The disease in question is imminently treatable and foreboding without treatment
- The treatment (or the next step) is not seamless and has its own complications
- **The imaging should alter clinical decision making** (i.e. the prevalence of disease in the population upon which the imaging modality is used should neither be too high nor too low)
Why might an imaging modality not improve outcomes despite high diagnostic accuracy and pretty pictures?

• Treatment fails

• If there is no difference between the intensity of treatment in the group that tests positive versus the group that tests negative
  a) If the modality is “ahead” of the intervention
  b) Physicians pay no attention to the test result

Thus, although much is being done for the qualification and quantification of vulnerable plaque, the modality will not be considered value for money if all the physician says to the patient is “drink diet coke, take an atorvastatin and practice yoga”
The imaging should alter clinical decision making

**Treat threshold** – if the pre-test probability exceeds this then treat without testing (straight to CA)

**Test threshold** – if the pre-test probability is below is then no need to test or treat (reassure!)

For imaging to alter clinical decision making the pre-test probability should really be between the treat and test thresholds (in theory).

(Does a test threshold actually exist?)
A new modality

Must provide incremental information compared to the existing one and that incremental information must be shown to, on average, carry it across one of the two thresholds.
Factors determining the more cost-effective modality between SPECT and stress MRI

The *more effective* imaging modality:

- More sensitive
- More specific
- More unequivocal imaging features (low “hedge” factor)
- More reproducible
- More diagnostic tests
Which is more important, sensitivity or specificity?

1. How much is already present (marginal gain).
2. The prevalence of the disease.
3. The cost of a false negative (missed case) or false positive (unnecessary catheter angiography/ revascularization)

Consequences of trading between sensitivity and specificity depends on the pre-test probability and the disposition of the positive case. Higher the cost of dealing with the positive case, and lower the pre-test probability, the more cost effective modality will be the one with a higher specificity

As a general rule, lack of sensitivity is not the problem. Overcalls and poor specificity are the major issues to deal with.
Do either SPECT or MRI have unique false positives and negatives?

- SPECT – triple vessel/ left main disease – balanced ischemia (false negative)

- MRI – concentrated gadolinium effect (false positive)

- SPECT – attenuation artifact due to habitus
Factors determining the more cost-effective modality between SPECT and stress MRI

1. Test indeterminate rate
2. The disposition of the patient with an indeterminate test

The test can be indeterminate because of sub-maximal stress (HR < 85% of maximal) or poor imaging quality (difficulty achieving ECG synchronization, breath hold issues, claustrophobia). A test could also be considered equivocal in the presence of a predictable yet unavoidable artifact that is known to predictably alter the interpretation.

What happens to the patient who has an indeterminate test?
- Depends on the pre-test probability and on the unique patient interaction
- further testing (cardiac CT for equivocal SPECT)
- straight to CA
- medical therapy +/- repeat testing in 6 months

Despite the unique nature of these scenarios decision modeling must make assumptions, generalizations and use aggregates
Non diagnostic examination rates

Cardiac CT – 2 %
SPECT – 5 %
Stress Echo – 15 %
Exercise ECG – 22 %

Stress MRI ranges from 11 % (Nagel, Circulation, 1999) to 22 % (HTA, UK).
Personal experience – 0 %!
Factors determining the more cost effective modality between SPECT and stress MRI

The cost of the intervention the modality is trying to gate keep (the “next step” – i.e. the step after the positive result)

If one modality leads to fewer unnecessary “next steps” then the difference in costs between the modalities is exaggerated the more expensive the “next step”

The next step could be CA, trial of medical therapy or PCI
Does the “next step” need to be CA?

- If the patient can be triaged into two groups - low risk/ no additional benefit of revascularization and high risk/ additional benefit of revascularization then CA can be avoided.

- If that paradigm is in place the onus will be on the modality to prognosticate as well as diagnose CAD.
Can MRI prognosticate as well as SPECT?

Yes, but more studies are needed

Steel, Circ 2009
- Rev PD and LGE provides robust and complementary risk stratification
- Adjusted HR > 3
- LGE, even with negative PD, associated with 11 fold increase in death
- No LGE and no Rev PD – 1.9 % annual CD/MI
Factors determining the more cost effective modality between SPECT and stress MRI

The value of additional information

The LV ejection fraction.
State of the valves.
Anatomical imaging (coronary MRA).
Viability.

The factors can make stress MRI more effective in certain key patient populations (e.g. heart failure, suspected concomitant valvular heart disease, previous MI) by avoiding additional studies, optimizing therapy.

Coronary MRA (72, 87) – Schuijf, Am Heart Journal, 2006
Conceptual Framework for cardiac MRI as a comprehensive examination

Traditional Imaging → Non-comprehensive cardiac evaluation → Multiple tests
Appropriate: inappropriate catheter utilization

Cardiac MRI → Comprehensive cardiac evaluation
Improved accuracy → Single test
Increased Appropriate: Inappropriate catheter utilization
Costs

• Modality costs should include direct and indirect costs. Also consider induced costs/ downstream imaging.

• Medicare reimbursement Stress MRI - $535 (75563) and SPECT – $853 (78465)

• Costs from societal perspective includes all costs
<table>
<thead>
<tr>
<th>Authors</th>
<th>Pre-test probability</th>
<th>Outcome</th>
<th>Method/ modalities</th>
<th>Assumption</th>
<th>Findings</th>
<th>Comments</th>
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<tr>
<td>Dewey &amp; Hamm European Radiology, 2007</td>
<td>10-50%</td>
<td>Cost per correct diagnosis</td>
<td>Decision tree Stress MRI/ CT/ calcium score</td>
<td>Non-diagnostic test went straight to CA</td>
<td>Stress MRI not CE at any PTP</td>
<td>Used 11% indeterminate rate for stress MRI</td>
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<tr>
<td>Hernández and Vale, 2007</td>
<td>Low (10.5%)</td>
<td>Cost per QALY</td>
<td>Decision tree/ Markov model ECG-SPECT/ SPECT/ ECG/ straight CA</td>
<td>Non diagnostic test went straight to CA</td>
<td>ECG-SPECT ($5192 for 12.510 QALYs) cheapest. SPECT provided one additional QALY at $26249 (12.532 QALYs at $5529)</td>
<td>Model assumed all surviving false negatives would eventually be diagnosed in 10 years</td>
</tr>
<tr>
<td>Kuntz, Annals of Internal medicine 1999</td>
<td>Intermediate</td>
<td>Cost per QALY</td>
<td>Decision tree/ Markov Model No testing, ECG, stress Echo, SPECT and direct CA</td>
<td>No non-diagnostic tests</td>
<td>Stress echo more cost effective than SPECT when compared to ECG ($41,900 vs $54,800)</td>
<td>Unusually low specificity for SPECT (64%).</td>
</tr>
<tr>
<td>Garber and Solomon, Annals of Internal Medicine, 1999</td>
<td>Intermediate</td>
<td>Cost per QALY</td>
<td>Decision tree/ Markov Model ECG, Planar thallium, stress echo, SPECT, PET and direct CA</td>
<td>No non-diagnostic test</td>
<td>Stress echo dominated ECG and planar thallium. ICER for SPECT $75,000 relative to stress Echo. ICER for PET $640,000 relative to SPECT</td>
<td>Sensitivity/ specificity %: SPECT (88/77) Stress echo (76/88) Planar thallium (79/73) ECG (68/77) PET (91/82)</td>
</tr>
<tr>
<td>Ladapo, JACC 2009</td>
<td>Intermediate</td>
<td>Cost per QALY</td>
<td>Decision tree/ Markov Model CT, ECG, Stress Echo, SPECT and combination</td>
<td>Low risk had medical management and high risk had PCI/ CABG</td>
<td>CTA-ECG most effective</td>
<td>First to model prognosis, downstream CT resource use</td>
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Salient points

The difference in the effectiveness between the worst and the least performing study not a great deal.

Garber and Solomon:
7 days
PET - $1500 and stress echo - $265

Ladapo:
No test led to 13.32 QALYs and CTA-stress ECG led to 13.632 QALYs
Costs similar - $ 27, 580 - $35, 500
$25, 520 – CABG
$12, 840 – DES
$1750 - CA
Ladapo’s model was the only one that prognosticated
Problem with models

- Assumptions
- Aggregates may be correct in the aggregate although not applicable in any individual case
- Sequential tests are assumed to have the same test characteristics – i.e. they are considered to be conditionally independent
What if stress MRI was shown to dominate SPECT and we lived in a world where cardiologists and radiologists co-operated rather than competed what could possibly stop stress MRI from being the preferred modality?
Barriers to widespread adoption of stress MRI

- Purchase costs
- Training costs
- Perception of the difficulty of stress MRI
- What will the skilled nuclear imagers do?
- The huge body of prognostic literature for SPECT.
- Greater uncertainty of the value of a negative stress MRI
- Other radiological studies (“In the time that you will do one in patient stress MRI/ coronary MRA I can have the technologist do 3 knee MRIs”)

Take home points

• Better test characteristics are necessary but not sufficient to make one modality more cost effective than another
• The preference between improved sensitivity or specificity depends on the pre-test probability
• One of the most important factors determining the more cost effective imaging modality is the nature and cost of the “next step”
• Outcomes-based technology validation is likely to be the norm