Application of Coronary CT in the Emergency Department

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Outline

• The problem
• Coronary CT as the solution
  • ACRIN PA 4005 and ROMICAT II
• Up front decisions
• Who do you need?
• What do you need?
• Lingering issues
• Discussion
Acute Coronary Syndrome and the ED

- 8-10 million ED chest pain presentations/yr in US
- 85-95% have a final diagnosis other than MI or USA
- Many patients will have unnecessary admission (60%) and testing to exclude ACS
- High cost to society ($5 billion/year), hospital resources not available for those who need it
- But, big downside for missed diagnosis (up to 5%)
- General agreement in US, <1% miss rate is needed
  - Clinical exam, risk factors, and markers can’t do it
Acute Chest Pain Presentation: Different Perceptions

- Cardiologist wants to know:
  - Is the patient having an ACS (AMI or USA)?
  - Risk of short term morbidity
  - Need for acute intervention
  - Long term risk assessment

- ER doc wants to know:
  - When is this patient getting out of my ER?
  - Will something bad happen if I send them home?
  - Can I make this someone else’s problem?
  - Admit to cardiology for rx
  - Put in observation unit
Goals for ED Chest Pain Evaluation

• Exclude or diagnose causes with morbidity if untreated
  • Triage to appropriate rx - cath lab, anticoagulation for PE
  • Specificity, accuracy, positive predictive value
• Discharge safely if negative - sensitivity, negative predictive value. Goal is <1% 30-day event rate
• Provide good “warranty period” for negative eval
  • ED doc assured nothing bad will happen
  • Can reduce need for repeat workup if patient returns
• Provide risk assessment for outpatient treatment
  • Maybe motivation for lifestyle modification
• Do it efficiently and as cheaply as possible
  • ED overcrowding leads to bad care for everyone
**TIMI RISK SCORE for UA/NSTEMI**

<table>
<thead>
<tr>
<th>Historical Points</th>
<th>Risk of Cardiac Events (%) by 14 Days in TIMI 11B*</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Age ≥ 65</strong></td>
<td>0/1 3 5</td>
</tr>
<tr>
<td>≥ 3 CAD risk factors (FHx, HTN, T-dial, DM, active smoker)</td>
<td>2 3 8</td>
</tr>
<tr>
<td>Known CAD (stenosis ≥ 50%)</td>
<td>3 5 13</td>
</tr>
<tr>
<td>ASA use in past 7 days</td>
<td>4 7 20</td>
</tr>
<tr>
<td><strong>Presentation</strong></td>
<td></td>
</tr>
<tr>
<td>Recent (&lt;24H) severe angina</td>
<td>5 12</td>
</tr>
<tr>
<td>↑ cardiac markers</td>
<td>6/7 19 41</td>
</tr>
<tr>
<td>ST deviation ≥ 0.5 mm</td>
<td></td>
</tr>
</tbody>
</table>

*Risk score = Total Points (0 - 7)*

For more info go to www.timi.org

Antman et al. JAMA 2000; 284: 835 - 842

<table>
<thead>
<tr>
<th>Cut-off score</th>
<th>Sensitivity (95% CI)</th>
<th>Specificity (95% CI)</th>
<th>Positive likelihood ratio (95% CI)</th>
<th>Negative likelihood ratio (95% CI)</th>
<th>No. (%) admitted to hospital*</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt; 0</td>
<td>97.2 (96.4–97.8)</td>
<td>25.0 (24.3–25.7)</td>
<td>1.30 (1.28–1.31)</td>
<td>0.11 (0.09–0.15)</td>
<td>12 231 (78.1)</td>
</tr>
<tr>
<td>&gt; 1</td>
<td>90.6 (89.3–91.8)</td>
<td>51.0 (50.0–52.0)</td>
<td>1.84 (1.80–1.89)</td>
<td>0.19 (0.16–0.21)</td>
<td>8 599 (54.9)</td>
</tr>
<tr>
<td>&gt; 2</td>
<td>79.7 (78.0–81.4)</td>
<td>70.4 (69.6–71.1)</td>
<td>2.69 (2.60–2.78)</td>
<td>0.29 (0.27–0.31)</td>
<td>5 737 (36.6)</td>
</tr>
<tr>
<td>&gt; 3</td>
<td>57.5 (55.4–59.6)</td>
<td>85.5 (84.9–86.1)</td>
<td>3.97 (3.76–4.20)</td>
<td>0.50 (0.47–0.52)</td>
<td>3 206 (20.5)</td>
</tr>
<tr>
<td>&gt; 4</td>
<td>33.2 (31.3–35.3)</td>
<td>96.6 (96.3–96.9)</td>
<td>9.70 (8.7–10.8)</td>
<td>0.69 (0.67–0.71)</td>
<td>1 188 (7.6)</td>
</tr>
</tbody>
</table>

Note: CI = confidence interval.
*The potential proportion of patients who would be admitted to hospital if the TIMI risk score alone were used to triage patients.

Stress Testing vs. Cath

- Patients with previous negative stress vs. no prior test
  - No change in admission rate
  - No change in ED recidivism rate
  - No change in cath rate
- Previous negative stress test does not decrease 30-day adverse events in those presenting with chest pain
- Coronary angiography vs. stress testing
  - Fewer repeat ED visits
  - Fewer hospitalizations
  - Higher satisfaction rates
  - Better understanding of disease

Shaver et al. Acad EM 2004
deFillipi et al. JACC 2001
CT as the Solution

• Single center trials (some large)
  • CT is safe (<1% 30-day event rate - now 1 yr f/u)
  • CT is efficient (8-12 hrs vs. 24 hrs usual care)
  • CT costs less ($250 - $2500 savings per pt)
  • CT reduces repeat ED visits and readmissions

• Multicenter trials
  • CT-STAT
  • ACRIN PA 4005 and ROMICAT II

• Most (not all!) payers endorse this application
• CMS draft NCD endorsed this specific application

• Why does CT work? It acts as a surrogate for cath.
  • ED physicians and patients believe the results
<table>
<thead>
<tr>
<th>Study</th>
<th>Population</th>
<th>N</th>
<th>Follow-up period</th>
<th>Event rate in negative group</th>
<th>Nondiagnostic rate</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Goldstein, JACC 2007</td>
<td>low-intermediate risk</td>
<td>99</td>
<td>6 months</td>
<td>0%</td>
<td>11%</td>
<td>RCT, stress 26-70%</td>
</tr>
<tr>
<td>Hoffmann, Circ 2006, JACC Imaging 2011</td>
<td>low-intermediate (very few high)</td>
<td>368</td>
<td>2 years</td>
<td>0% 30-days, 4.6% 2 years</td>
<td>9%</td>
<td>prospective obs, CT not for decisions</td>
</tr>
<tr>
<td>Hollander, Ann Emer Med 2007</td>
<td>low-intermediate (most low)</td>
<td>588</td>
<td>1 year</td>
<td>0% 30 days, 0.2% 1 year</td>
<td>not recorded</td>
<td>observational</td>
</tr>
<tr>
<td>Rubenshtein, Circ 2007</td>
<td>intermediate-high</td>
<td>58</td>
<td>15 months</td>
<td>0% 30 days, 3% 15 months</td>
<td>0%</td>
<td>observational</td>
</tr>
<tr>
<td>Beigel, Isr Med Assn J, 2010</td>
<td>low-intermediate</td>
<td>445</td>
<td>mean 236 days</td>
<td>unknown, overall 2.4%</td>
<td>7%, retrospective</td>
<td>observational</td>
</tr>
<tr>
<td>Winchester, Intl J Card, 2010</td>
<td>low to intermediate</td>
<td>50</td>
<td>3 months</td>
<td>0</td>
<td>0%</td>
<td>observational</td>
</tr>
<tr>
<td>Goldstein, JACC 2011</td>
<td>low-intermediate</td>
<td>376</td>
<td>6 month</td>
<td>0.6%</td>
<td>unknown</td>
<td>RCT, multictr</td>
</tr>
<tr>
<td>Shuman, AJR 2010</td>
<td>low-intermediate</td>
<td>75</td>
<td>12 months</td>
<td>0%</td>
<td>8%</td>
<td>observational</td>
</tr>
<tr>
<td>Hansen, Heart Lung Circ 2010</td>
<td>intermediate</td>
<td>85</td>
<td>mean 355 days</td>
<td>0%</td>
<td>unknown</td>
<td>observational</td>
</tr>
</tbody>
</table>
Single Center Trials

- Observational trials
  - ROMICAT 368 pts, 50% neg CT, no ACS
  - Hollander et al., 568 pts, no MACE w/neg CT

- Single center RCT
  - Goldstein et. al, 197 pts, ↓LOS & cost, no MACE
CT-STAT

• Multicenter RCT in Michigan
• 699 pts at 16 sites – CT vs. SPECT-MPI
• 54% reduction in time to diagnosis
• 38% cost savings
• MACE after negative test
  • 2/268 CT (0.75%, 95% CI 0.09-2.7%)
  • 1/266 SPECT-MPI (0.38%, 95% CI 0.01-2.1%)
CT Angiography for Safe Discharge of Patients with Possible Acute Coronary Syndromes

Harold I. Litt, M.D., Ph.D., Constantine Gatsonis, Ph.D., Brad Snyder, M.S., Harjit Singh, M.D., Chadwick D. Miller, M.D., Daniel W. Enrikin, M.D., James M. Leaming, M.D., Laurence J. Gavin, M.D., Charissa B. Pacella, M.D., and Judd E. Hollander, M.D.
Methods 1 – ACRIN PA 4005

• Multicenter RCT of CCTA based strategy vs. traditional care (2:1) at 5 sites

• Primary hypothesis
  — Patients without significant CAD by CCTA have <1% rate of 30-day cardiac death or MI

• Secondary aims – CCTA vs. trad care
  — ED discharge rate and length of stay
  — 30-day MACE and revascularization
  — 30-day resource utilization
Methods 2

- **Eligibility criteria**
  - >30 yrs, signs/symptoms of potential ACS
  - TIMI score 0-2, no acute ischemia on ECG
  - Need for admission or testing to exclude ACS

- **Exclusion criteria**
  - Clearly non-cardiac pain
  - Comorbidity requiring hospital admission
  - Normal cath or CCTA within previous year
  - Contraindications to CCTA
  - Post-randomization exclusions
    - CrCl < 60 or subject received PE protocol CT
Methods 3 - Testing

• 64 slice or greater CT
  — Noncontrast scan for calcium scoring
  — Contrast enhanced CCTA
  — Use of $\beta$-blockers and NTG per local protocol
  — All readers ACC/AHA level 3
    • Local interpretations for clinical decisions
    • In analysis, stenosis quantified
      — None, <50%, 50-69%, $\geq$70%

• Stress testing per local protocol
  — Imaging or not, choice of modality
Methods 4 – Follow-up

• 30-day direct patient contact
  — AMI, rehospitalization, revascularization
  — Cardiac testing, cardiology visits, med use

• Record review
  — All potential cardiac hospitalizations
  — All potential MACE
  — If no direct patient contact
    • Including neighboring hospitals

• SSDI if no other survival information
  • Social Security Death Index
Methods 5 – Outcomes and Definitions

• All MACE reviewed by adjudication cmte

• Significant CAD
  — ≥50% stenosis in LM, LAD, CX, RCA or 1st order branches
  — Indeterminate studies
    • Any non-diagnostic segments and no significant CAD elsewhere

• ACS – AMI or confirmed unstable angina
  — Reversible ischemia or ≥ 70% stenosis at cath
Results 1

- 1392 subjects July 2009 – Nov 2011
- 22 removed post-randomization (most CrCl)
- 908 randomized to CCTA, 462 traditional care
- Groups well matched, 60% AA/black

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<table>
<thead>
<tr>
<th>Characteristic</th>
<th>CCTA (N=908)</th>
<th>Traditional Care (N=462)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, Mean +/- SD (Range)</td>
<td>49 +/- 8.9 (30-78)</td>
<td>50 +/- 9.5 (30-83)</td>
</tr>
<tr>
<td>Gender</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>443 (49%)</td>
<td>202 (44%)</td>
</tr>
<tr>
<td>Female</td>
<td>465 (51%)</td>
<td>260 (56%)</td>
</tr>
<tr>
<td>Ethnicity</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hispanic/Latino</td>
<td>21 (2%)</td>
<td>11 (2%)</td>
</tr>
<tr>
<td>Not Hispanic/Latino</td>
<td>867 (95%)</td>
<td>439 (95%)</td>
</tr>
<tr>
<td>Unknown</td>
<td>20 (2%)</td>
<td>12 (3%)</td>
</tr>
<tr>
<td>Race†</td>
<td></td>
<td></td>
</tr>
<tr>
<td>American Indian/Alaskan Native</td>
<td>5 (0.6%)</td>
<td>6 (1%)</td>
</tr>
<tr>
<td>Asian</td>
<td>11 (1%)</td>
<td>7 (2%)</td>
</tr>
<tr>
<td>Black/African American</td>
<td>525 (58%)</td>
<td>288 (62%)</td>
</tr>
<tr>
<td>Native Hawaiian/other Pacific Islander</td>
<td>2 (0.2%)</td>
<td>0</td>
</tr>
<tr>
<td>White</td>
<td>361 (40%)</td>
<td>162 (35%)</td>
</tr>
<tr>
<td>Unknown</td>
<td>9 (1%)</td>
<td>4 (0.9%)</td>
</tr>
<tr>
<td>Cardiac history and risk factors†</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hypertension</td>
<td>463 (51%)</td>
<td>232 (50%)</td>
</tr>
<tr>
<td>Hypercholesterolemia</td>
<td>249 (27%)</td>
<td>118 (26%)</td>
</tr>
<tr>
<td>Family History of CAD</td>
<td>268 (30%)</td>
<td>126 (27%)</td>
</tr>
<tr>
<td>Diabetes Mellitus</td>
<td>130 (14%)</td>
<td>64 (14%)</td>
</tr>
<tr>
<td>Current Tobacco use</td>
<td>291 (32%)</td>
<td>156 (34%)</td>
</tr>
<tr>
<td>Cocaine use in last week</td>
<td>49 (5%)</td>
<td>20 (4%)</td>
</tr>
<tr>
<td>Myocardial infarction</td>
<td>10 (1%)</td>
<td>6 (1%)</td>
</tr>
<tr>
<td>Heart failure</td>
<td>10 (1%)</td>
<td>9 (2%)</td>
</tr>
</tbody>
</table>

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<table>
<thead>
<tr>
<th>Characteristic</th>
<th>CCTA (N=908)</th>
<th>Traditional Care (N=462)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pulse at presentation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&gt;= 80 beats/minute</td>
<td>519 (57%)</td>
<td>250 (54%)</td>
</tr>
<tr>
<td>60 - 79 beats/minute</td>
<td>356 (40%)</td>
<td>197 (42%)</td>
</tr>
<tr>
<td>&lt; 60 beats/minute</td>
<td>33 (4%)</td>
<td>15 (3%)</td>
</tr>
<tr>
<td>Presenting electrocardiogram</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Normal</td>
<td>584 (64%)</td>
<td>299 (65%)</td>
</tr>
<tr>
<td>Nonspecific</td>
<td>208 (23%)</td>
<td>111 (24%)</td>
</tr>
<tr>
<td>Early repolarization</td>
<td>24 (3%)</td>
<td>14 (3%)</td>
</tr>
<tr>
<td>Non-diagnostic</td>
<td>68 (7%)</td>
<td>24 (5%)</td>
</tr>
<tr>
<td>Ischemia known to be old</td>
<td>11 (1%)</td>
<td>6 (1%)</td>
</tr>
<tr>
<td>Ischemia not known to be old</td>
<td>10 (1%)</td>
<td>7 (2%)</td>
</tr>
<tr>
<td>ST Elevation consistent with AMI-old</td>
<td>2 (0.2%)</td>
<td>0</td>
</tr>
<tr>
<td>Other/Unknown</td>
<td>1 (0.1%)</td>
<td>1 (0.2%)</td>
</tr>
<tr>
<td>TIMI Risk Score</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>461 (51%)</td>
<td>234 (51%)</td>
</tr>
<tr>
<td>1</td>
<td>325 (36%)</td>
<td>166 (36%)</td>
</tr>
<tr>
<td>2 or more</td>
<td>122 (13%)</td>
<td>62 (13%)</td>
</tr>
</tbody>
</table>
Results 2 – Index visit testing

- 16% didn’t get CT
  - 7-33% across sites
  - Elevated HR (27%)
  - MD decision (24%)
  - AMA/refused (15%)

- Similar cath rate
  - CT higher pos rate

- No testing
  - 9% vs. 36%

<table>
<thead>
<tr>
<th></th>
<th>CCTA (N=908)</th>
<th>Traditional Care (N=462)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CCTA Performed</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maximal stenosis &lt; 50%</td>
<td>640 (83%)</td>
<td>20 (77%)</td>
</tr>
<tr>
<td>Maximal stenosis 50-69%</td>
<td>52 (7%)</td>
<td>2 (8%)</td>
</tr>
<tr>
<td>Maximal stenosis ≥70%</td>
<td>28 (4%)</td>
<td>2 (8%)</td>
</tr>
<tr>
<td>Indeterminate/nondiagnostic</td>
<td>47 (6%)</td>
<td>2 (8%)</td>
</tr>
<tr>
<td><strong>Stress testing</strong> (with or without imaging)</td>
<td>N=124 (14%)</td>
<td>N=267 (58%)</td>
</tr>
<tr>
<td>Normal</td>
<td>98 (79%)</td>
<td>245 (92%)</td>
</tr>
<tr>
<td>Reversible ischemia</td>
<td>15 (12%)</td>
<td>16 (6%)</td>
</tr>
<tr>
<td>Indeterminate/nondiagnostic</td>
<td>11 (9%)</td>
<td>6 (2%)</td>
</tr>
<tr>
<td><strong>Cardiac catheterization performed</strong></td>
<td>N=37 (4%)</td>
<td>N=18 (4%)</td>
</tr>
<tr>
<td>Maximal stenosis &lt; 50%</td>
<td>9 (24%)</td>
<td>10 (56%)</td>
</tr>
<tr>
<td>Maximal stenosis ≥ 50%</td>
<td>28 (76%)</td>
<td>8 (44%)</td>
</tr>
<tr>
<td>No testing performed</td>
<td>80 (9%)</td>
<td>167 (36%)</td>
</tr>
</tbody>
</table>

Penn Medicine
Results 3 - Safety

• No 30-day MACE in 640 pts with neg CTA
  —0% event rate, 95% CI 0–0.57%

• Secondary aims - 30-day CCTA vs. trad

<table>
<thead>
<tr>
<th>Outcome</th>
<th>Coronary CTA (N=908)</th>
<th>Traditional Care (N=462)</th>
<th>% Difference ** (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cardiovascular Events</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Death</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>AMI *</td>
<td>10 (1%)</td>
<td>5 (1%)</td>
<td>0.02% (-5.6, 5.7)</td>
</tr>
<tr>
<td>Composite Death &amp; AMI</td>
<td>10 (1%)</td>
<td>5 (1%)</td>
<td>0.02% (-5.6, 5.7)</td>
</tr>
<tr>
<td>Revascularization</td>
<td>24/893 (2.7%)</td>
<td>6/457 (1.3%)</td>
<td>1.4% (-4.3, 7.0)</td>
</tr>
</tbody>
</table>

• One serious AE in each arm
  —Bradycardia related to meds for HR control
Results 4 – Efficiency

• CCTA more often discharged from ED
  — 50% vs. 23% (95% CI 21.4-33.2)
• LOS shorter
  — Overall CCTA vs. trad care: 18 vs. 25 hrs*
  — Negative testing: 12 vs. 25 hrs*
  — Per protocol (had CCTA or stress testing)
    • Overall 15 vs. 26 hrs*
    • Negative CCTA or stress testing (trad care) 12 vs. 25 hrs*
    • *p<0.001
• More CCTA pts diagnosed with CAD
  — 9.0 vs. 3.5% (95% CI 0-11.2)
Results 5 – Resource Utilization

- No significant differences in 30-day resource utilization (CCTA vs. trad care)

<table>
<thead>
<tr>
<th>Use of Resources</th>
<th>CCTA-based (%)</th>
<th>Traditional Care (%)</th>
<th>95% CI for Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Catheterization</td>
<td>5.1</td>
<td>4.2</td>
<td>-4.8 to 6.6</td>
</tr>
<tr>
<td>Revascularization</td>
<td>2.7</td>
<td>1.3</td>
<td>-4.3 to 7.0</td>
</tr>
<tr>
<td>Repeat ED visit</td>
<td>8.0</td>
<td>7.5</td>
<td>-5.2 to 6.2</td>
</tr>
<tr>
<td>Re-hospitalization</td>
<td>3.1</td>
<td>2.4</td>
<td>-4.9 to 6.4</td>
</tr>
<tr>
<td>Cardiologist visit</td>
<td>7.1</td>
<td>3.8</td>
<td>-2.4 to 9.0</td>
</tr>
</tbody>
</table>

- We are obtaining 1 year follow-up
Discussion 1

- CCTA-based strategy safe and efficient
  - Upper limit of CI for 30-day MACE < 1%
  - Increased rate of ED discharge, shorter LOS
  - Fewer negative caths, more CAD diagnoses

- Previous trials results similar but
  - Observational or no comparison arm
  - RCTs not large enough to demonstrate acceptable safety
  - Wider range of trad care in our trial
  - “Real world” management and disposition
Discussion 2 - Limitations

• Comparative RCT needs ~50,000 subjects
  — Low event rate in population studies
  — Study powered for conservative safety goal

• ? Need for any testing in these patients
  — Enrolled only those needing admission/testing
  — Still 9% vs. 36% received no testing
  — Note: there have been no RCTs comparing testing with no testing!
  — Is 1% the right number for risk tolerance?

• Low to intermediate risk patients only
  — Can’t extrapolate to higher risk groups
Studies Comparing Testing with No Testing

  • Observational cohort
  • Inpt (21%) vs. outpt stress (8%) vs. no testing
  • 1.3% MACE in no testing group at 30 days

  • Observational cohort of patients < 40 years
  • 93% no testing, 7% testing
  • 0.4% MACE in no testing group at 30 days

• Milano, et al. Crit Pathw Cardiol 2011
  • Retrospective review, pts who complied with follow-up outpatient stress testing vs. non
  • No MI in 58% of pts who did not have testing
    • Mean 8 months followup
    • 2 deaths, unknown cause (1% event rate)
Comparing Testing with No Testing

Special Article ONLINE FIRST
Chest Pain in the Emergency Department
The Case Against Our Current Practice of Routine Noninvasive Testing ONLINE FIRST
Vinay Prasad, MD; Michael Cheung, MD; Adam Cifu, MD

EDITORIAL
Coronary CT Angiography for Acute Chest Pain
Rita F. Redberg, M.D.

The decision regarding the need for diagnostic testing in these patients usually can be safely deferred to outpatient follow-up within a few weeks after the visit to the emergency department.
# Stress Echo Evidence

<table>
<thead>
<tr>
<th>Study</th>
<th>Population</th>
<th>N</th>
<th>Follow-up period</th>
<th>Event rate in negative group</th>
<th>Nondiagnostic rate</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bholasingh, JACC 2003</td>
<td>low risk</td>
<td>377</td>
<td>6 months</td>
<td>4.0%</td>
<td>5.7%</td>
<td></td>
</tr>
<tr>
<td>Trippi, JACC 1997</td>
<td>low-intermediate</td>
<td>139</td>
<td>3 months</td>
<td>1.5%</td>
<td>2.9%</td>
<td>most dipyridamole</td>
</tr>
<tr>
<td>Orlandi, AJC 2000</td>
<td>low-intermediate</td>
<td>195</td>
<td>35 days</td>
<td>0%</td>
<td>9.2%</td>
<td></td>
</tr>
<tr>
<td>Hartlage Int J Cardiovasc Im</td>
<td>low</td>
<td>166</td>
<td>mean 320 days (record review)</td>
<td>1.8%</td>
<td>retrospective</td>
<td></td>
</tr>
<tr>
<td>Galbazzi, AJC 2011</td>
<td>low-intermediate 50% TIMI 2-4</td>
<td>545</td>
<td>mean 361 days</td>
<td>1%</td>
<td>0%, retrospective</td>
<td>dipryridamole perfusion</td>
</tr>
<tr>
<td>Beigel, Isr Med Assn J, 2010</td>
<td>low-intermediate</td>
<td>58</td>
<td>mean 236 days</td>
<td>unknown, overall 2.4%</td>
<td>1.7%, retrospective</td>
<td>most pts had CT or MPS</td>
</tr>
<tr>
<td>Lerakis, Intl J Card, 2010</td>
<td>low to intermediate</td>
<td>204</td>
<td>mean 321 days (record review)</td>
<td>1.1%</td>
<td>13% (submaximal)</td>
<td></td>
</tr>
<tr>
<td>Jeetley, Eur Heart J, 2007</td>
<td>low-intermediate 69% TIMI 2-4</td>
<td>210</td>
<td>mean 8.7 months</td>
<td>5%</td>
<td>3%</td>
<td>mix of pharm and exercise</td>
</tr>
<tr>
<td>Bedetti, Intl J Card 2005</td>
<td>low-intermediate</td>
<td>552</td>
<td>mean 13 months</td>
<td>1.2%</td>
<td>0%</td>
<td>mostly dipyridamole</td>
</tr>
<tr>
<td>Tsutsui, Echo 2005</td>
<td>low to high (some with +troponins)</td>
<td>158</td>
<td>mean 16 months</td>
<td>12% at 3 years</td>
<td>0%</td>
<td></td>
</tr>
<tr>
<td>Conti, AHJ 2005</td>
<td>low to intermediate</td>
<td>529</td>
<td>6 months (record review)</td>
<td>5% (includes &gt;50% stenosis)</td>
<td>5%</td>
<td>all exercise</td>
</tr>
<tr>
<td>Nucifora, AJC 2007</td>
<td>low</td>
<td>110</td>
<td>2 months</td>
<td>0%</td>
<td>0%</td>
<td>RCT with exercise ECG</td>
</tr>
</tbody>
</table>
Discussion 3 – CT Limitations

• **Radiation exposure** – tracked in study
  — Very technology dependent
  — Most CCTA now lower dose than SPECT-MPI

• 16% randomized to CCTA didn’t get it
  — Elevated HR most common cause (27%)
  — Very technology dependent, \(\downarrow\) over time

• More diagnosed with incidental CAD
  — Better prevention or more testing?
Radiation Doses in ACRIN PA 4005

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>10.93</td>
</tr>
<tr>
<td>Std Dev</td>
<td>5.79</td>
</tr>
<tr>
<td>Minimum</td>
<td>1.07</td>
</tr>
<tr>
<td>Lower Quartile</td>
<td>6.54</td>
</tr>
<tr>
<td>Median</td>
<td>10.60</td>
</tr>
<tr>
<td>Upper Quartile</td>
<td>14.54</td>
</tr>
<tr>
<td>Maximum</td>
<td>37.21</td>
</tr>
</tbody>
</table>

Radiation Dose Histogram

Total Radiation Effective Dose across all Scans
Overall Dose Trend
### Doses with Latest Generation Scanner

**Baseline Data 3/10-5/11**
- **Max Dose**: 27.3 mSv
- **Min Dose**: 1.4 mSv
- **Mean Dose**: 10.0 mSv

<table>
<thead>
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</tr>
</thead>
<tbody>
<tr>
<td>Max Dose</td>
<td>19.2</td>
<td>15.6</td>
<td>15.2</td>
<td>23.8</td>
<td>19.5</td>
<td>16.8</td>
<td>27.9</td>
<td>25.1</td>
<td>23.7</td>
<td>16.9</td>
<td>26.5</td>
<td>14.4</td>
</tr>
<tr>
<td>Min Dose</td>
<td>1.4</td>
<td>0.9</td>
<td>1.5</td>
<td>1.7</td>
<td>1.3</td>
<td>1.9</td>
<td>0.8</td>
<td>0.7</td>
<td>1.5</td>
<td>0.9</td>
<td>1.3</td>
<td>1.2</td>
</tr>
<tr>
<td>Mean Dose</td>
<td>2.5</td>
<td>4.2</td>
<td>4.5</td>
<td>6.8</td>
<td>6.1</td>
<td>5.8</td>
<td>7.7</td>
<td>5.2</td>
<td>5.4</td>
<td>5.9</td>
<td>4.8</td>
<td>4.5</td>
</tr>
<tr>
<td>%&lt;5 mSv</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>60%</td>
<td>58%</td>
<td>76%</td>
<td>69%</td>
<td></td>
</tr>
<tr>
<td>%&gt;10 mSv</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>12%</td>
<td>12%</td>
<td>8%</td>
<td>13%</td>
<td></td>
</tr>
</tbody>
</table>
AAPM Statement on Radiation from Medical Imaging

•...Risks of medical imaging at effective doses below 50 mSv for single procedures or 100 mSv for multiple procedures over short time periods are too low to be detectable and may be nonexistent. Predictions of hypothetical cancer incidence and deaths in patient populations exposed to such low doses are highly speculative and should be discouraged. These predictions are harmful because they lead to sensationalistic articles in the public media that cause some patients and parents to refuse medical imaging procedures, placing them at substantial risk by not receiving the clinical benefits of the prescribed procedures.
Conclusions

- CCTA as first test for low-intermediate risk pts presenting to EDs with potential ACS
  - Safety
  - Efficiency
    - Increased ED discharge rates
    - Reduced length of stay

- Long term follow-up needed
  - Resource utilization
  - Effects of CAD diagnosis on outcomes
ROMICAT II

- Multicenter trial (9 centers) of 1000 pts
  - Funded by NHLBI
- Randomized to CCTA vs. usual care
- Somewhat higher risk population
  - 54 years old vs. 50 ACRIN PA 4005
  - 65% Caucasian
  - Overall 7.5% ACS rate vs. 4.0% ACRIN PA 4005
- Similar results
  - LOS 22 hrs CCTA vs. 31 hrs usual care
  - Safety: 28-day MACE in negative group
    - 0.4% CCTA vs. 1.0% usual care
  - Efficiency: 47% vs. 12% direct ED discharge
ROMICAT II - Some Differences

- Higher cath rate: 12% vs. 8%
  - Slightly higher revascularization rate: 6% vs. 4%
- Tracked total radiation dose
  - CCTA 14 mSv vs. usual care 5 mSv
  - Difference no testing rate: 2% vs. 22%
- Total costs measured at 5 sites
  - ED visit cheaper in CCTA: $2053 vs. $2532
  - Hospital costs more in CCTA: $1950 vs. $1297
  - Overall care similar: $4004 vs. $3828
Penn Cost, LOS, and Safety Analysis

<table>
<thead>
<tr>
<th></th>
<th>Immediate CTA (n=98)</th>
<th>CDU / CTA (n=102)</th>
<th>CDU Stress (n=154)</th>
<th>Usual Care (n=289)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total Facility Cost, $ (IQR)</strong></td>
<td>$1,240 (723–1,943)</td>
<td>$2,318 (2,000–3,041)</td>
<td>$4,024 (3,322–4,751)</td>
<td>$2,913 (1,713–5,592)</td>
</tr>
<tr>
<td><strong>LOS, hrs (IQR)</strong></td>
<td>8.1 (5.9–13.7)</td>
<td>20.9 (15.1–26.5)</td>
<td>26.2 (21.3–32.1)</td>
<td>30.2 (24.0–73.1)</td>
</tr>
<tr>
<td><strong>% CAD (95% CI)</strong></td>
<td>5.1 (1.7%, 11.5%)</td>
<td>5.9 (2.2%, 12.4%)</td>
<td>5.8 (2.7%, 10.8%)</td>
<td>6.6 (4.0%, 10.1%)</td>
</tr>
<tr>
<td><strong>% 30-day Death / MI (95% CI)</strong></td>
<td>0 (0.0, 3.7%)</td>
<td>0 (0.0, 3.6%)</td>
<td>0.7 (0.1, 3.6%)</td>
<td>3.1 (1.4, 5.8%)</td>
</tr>
<tr>
<td><strong>% Rehospitalization &lt;30 days</strong></td>
<td>0</td>
<td>3.2</td>
<td>2.3</td>
<td>12.2</td>
</tr>
</tbody>
</table>
Modeling Cost Effectiveness

- Lapado, JACC 2009 – included effects of incidentals
  - CTA followed by stress ECG marginally maximized QALYs
  - Most cost effective in both men and women
  - Even including radiation effects (~1/2000 induced cancer)
- Lapado, AJR 2008 – CT vs. stress testing
  - CTA saves money in women, cost effective in both
- Priest, JACC CVI 2011
  - CTA followed by SPECT for intermediate results is cheapest and most cost effective
- Goehler, AJR 2011
  - CTA reduces cath rate compared to SPECT and Echo
  - CTA reduces costs and death rate
Up Front Decisions

• What type of patients do you want to study?
  • All chest pain (except obvious ACS by ECG)
  • Triple rule-out
  • Only those for r/o MI
  • Low risk
  • Intermediate risk
  • Age limits - upper and lower

• Discharge directly from ED or require obs unit stay?
  • Stakeholders and facilities
  • Will determine hours of coverage
Who Do You Need?

- Emergency Medicine physicians, nurses, NPs, etc.
  - Most important people, decide who gets test and what to do with results
- Performing and reading CT
  - CT techs - who knows cardiac? 3D tech?
  - Radiologist or cardiologist to supervise/interpret
    - Training for cardiologists to do triple rule-out?
    - Giving meds at scanner (IV beta-blocker, NTG)
- Cardiology - interventional and non
  - They have to deal with the positive studies
  - You will be impacting their stress testing business
- Hospital administration
  - reimbursement issues and additional staffing
What Do You Need?

• A protocol
  • Who gets the test, who doesn’t
  • Who is responsible for doing what
  • Beta blockers, scheduling, alerting CT when pt ready
  • What is a positive result and what do you do with it?
  • What is a negative result and what do you do with it?

• A scanner - 64 slice min - better technology helps
  • Prospective triggering? Decreased radiation but no function
    • Triage for intermediate lesions (+ or - WMA)
    • Myocarditis, non-ischemic cardiomyopathy
  • Use the ED scanner or another?
  • Are you a busy trauma or stroke center?
Penn Low Risk CT-based ACS Protocol

- TIMI score 0-2, Normal or near-normal ECG
  - Many pts are retrospectively TIMI 3
- Draw markers, serum Cr & order CT at same time
- ED gives beta blockers for HR>70 (inc. dual source)
  - Call CT techs when HR<70, or no response after 1 hour
  - CT may be done before first markers back
- Exclusion criteria
  - Age <30 unless cocaine use, generally women <40 yrs
  - Dual source - we do all pts even if HR>70
  - Single source - beta blocker contraindications & HR>70
    - Asthma, cocaine use in prior 3 days (benzos work)
    - Flexible with HR>70, our ED understands limitations
  - Other CT contraindication - renal function, contrast rxn
CT Operational Aspects

- Scanner availability for ED add-ons
  - We assume 6 studies/day at present
- All techs know cardiac, 3D tech until 7 pm
- Physician availability (all radiologists)
  - 7 am - 10 pm, weekends 8 am - 12 pm - in house
  - Attending and CVI fellow reads only at present (level 3)
  - Can fellows and residents prelim? (remember PE)
  - IV beta or Ca channel blocker if needed, NTG at scanner
Admission to Cardiology Pathway

- Lesion $\geq 50\%$ in any observed vessel
- Positive first markers
- Recommended protocol - don’t have to follow
  - $50\% < \text{stenosis} < 70\%$ - stress testing
  - $>70\%$ stenosis in main or 1st order - direct to cath
- 30-day and 1-year phone contact plus record review
  - Death, AMI, revascularization
  - Repeat ED visits, outpatient cardiac testing
Discharge Pathway

- No stenosis >=50% in any observed vessel
- No explanation for chest pain requiring admission
- Normal first markers
- Discharged with handout describing CT results
  - Discharge at discretion of ED attending
  - Outpt followup recommended for <50% stenosis or any calcified or non-calcified plaque
  - Cardiology followup for anomalous vessels, other cardiac findings not requiring admission
- 30-day & 1-year phone contact plus record review
  - Death, AMI, revascularization
  - Repeat ED visits, outpatient cardiac testing
Other Pathway

- Other cause of chest pain requiring treatment
- Co-morbidity requiring further observation or treatment
- Admitted or discharged with followup as appropriate
- 30-day and 1-year phone contact plus record review
  - Death, AMI, revascularization
  - Repeat ED visits, outpatient cardiac testing
Repeat ED Visits - Our Protocol

• Normal CT (no stenosis or plaque) good for 2 years
  • No imaging or stress, no rule out
  • Discharge with instructions and outpt followup

• Mild dz (<50% stenosis)
  • < 2 yrs - stress test
  • Plaque rupture - probably would have +troponin
  • Borderline stenosis now hemodynamically significant
  • > 2 yrs - repeat CT - anatomy may have changed
  • May extend this time given our recent publication

• Previous >50% with negative stress test - repeat stress
  • Disease progression
  • Inadequate or false negative stress
CT Disadvantages

- Can’t be applied to everyone (~15%)
  - Renal impairment
  - High heart rate - how high depends upon technology used
  - Contrast allergy
  - Very large patients (>180 kg)
- Radiation
  - 10 mSv average dose for gated studies
  - 2-4 mSv for triggered studies, no function
- Incidental findings problem
- Low PPV of positive study
  - Especially as CAD rate goes up
Other Findings in 721 CT Exams 10/07-8/09

• No other findings 195 (27%)

• Likely causes of chest pain (12%)
  • Pneumonia/other lung parenchyma issues 58
  • Pulmonary embolism 2, aortic dissection 1
  • Pulmonary edema 2, pleural effusions 6
  • Fractures, esophageal mass, perforation, breast mass, lung mass

• Possible causes of chest pain (19%)
  • Hiatal hernia 76
  • Pulmonary hypertension 34
  • Aortic aneurysm 25
Truly “Incidental” Findings

- 42% of patients
- Pulmonary nodules 181 (25% - agrees with literature)
  - Follow-up recommended in 63 (9% of patients)
  - Follow-up performed in 17 (only in our system)
  - At least 5 lung cancers, so far, that we know about
- Emphysema 72 (10%)
- Mediastinal adenopathy 40 (5.5%)
  - some related to likely causes of chest pain
What is a Triple Rule-Out Scan?

• Evaluate 3 common causes of chest pain at once
  • Coronary disease
  • Pulmonary embolism
  • Aortic dissection

• Longer scan, but what defines a TRO scan
  • Aortic arch to heart base “2.5 rule out”
  • Thoracic inlet through lung bases
  • What about the abdominal aorta?

• Can you do it?
  • Opacify all structures well
  • Diagnostic images of coronaries

• Is it necessary?
  • Improved diagnostic yield or decreased testing
Triple Rule Out - Evidence


Triple Rule Out - Evidence

- Can you do it?
  - 3 studies by Halpern, et. al. (Jefferson, Philadelphia)
  - TRO image quality = dedicated coronary CT
  - Coronary, pulmonary, aortic opacification equal
  - TRO dose 30% > CCT (aorta to base only)
    - 50-125% increase for whole chest scan

- Is it necessary?
  - Jefferson - 11% +CAD, 1.5% +PE, 0.5% +dissection
    - Would you have seen PE & dissection on CCT?
  - Penn - 3500 ED coro CT 2007-11, 10% +CAD
    - 5 +PE (0.14%), 1 (0.03%) +dissection
    - We use three phase contrast injection
      - Preserves some RV and PA opacification
Is it Necessary?

- **CAPTURE - AJC March 2011;107(5):643-50**
  - ED pts referred for aortic, PE, or coronary CT
  - Randomized to dedicated vs. TRO protocol
  - TRO more radiation, no change in LOS, cost, downstream testing, or event rate

- **Stony Brook - presented at ACC 2011**
  - Retrospective analysis
  - TRO vs. dedicated PE or aorta study (not cardiac)
  - TRO lower dose, less downstream testing

- **Beaumont - JCCT May-Jun 2011;5(3):165-171**
  - Retrospective analysis TRO vs. cardiac CTA
  - Dx yield 14.3 vs. 16.3%, 1.1 vs 0.2% PE, zero dissection
  - TRO higher dose, more downstream testing
Newer Technology

- Prospective triggering
  - Am J Cardiol 2011 April 1; 107(7):1093-1098
  - 62% drop in dose. 7.5 vs. 19.4 mSv

- 320 slice detector
  - European Radiology 2011; 21(7): 1416-1423
    - Nongated chest (aorta to base) plus triggered heart
      - HR<65, BMI <30 (avg 25), 100 kVp. 60 ml, 2-3 mSv.
  - Intl J Cardiovasc Imaging 2012 May
    - Volume vs. helical scans (pro or retro), whole chest
      - avg BMI 23, 8.0 vs. 13.3 mSv, 65-100 ml

- High pitch dual source - needs low HR
  - Invest Radiol 2010 Feb; 45(2): 64-71. Phantom 2.65 mSv
  - Eur Soc Cardio 2010. 72 pts, HR< 60, 3.5 mSv
    - 2% nondiagnostic, 8% positive for PE
Why Would You Want to Do It?

• Chest pain can be nonspecific
  • Sometimes you really don’t know

• A single test is easier
  • ER docs only have to know about one test
  • Techs only have to know how to do one test
  • Might reduce need for more testing
Why Might You Not Want to Do It?

- PE and acute aortic syndrome are rare in appropriately selected ACS patients, at risk populations don’t overlap
  - ACS - 40-60 year old men, 50-70 year old women
  - Acute aortic syndrome
    - Young pts with abnormal aortas or older pts with HTN
    - Older patients with severe atherosclerosis (PAU, IMH)
  - Acute PE
    - Older cancer or debilitated pts, rarely young women

- Technical issues
  - Complicates protocol choices
  - Low dose options don’t apply to many (most?) patients
  - All techs need to know how to do it, and all radiologists/cardiologists need to know how to read it
How I See It

• Cardiac CT
  • You will always see a dissection
  • But might miss an IMH
  • You might miss a PE

• PE CT
  • You will probably see a dissection
  • But might miss an IMH
  • You will probably miss CAD

• Aortic CT
  • If gated, you will probably see significant CAD
  • You might miss a PE

• All of the above will show other causes of CP
  • But only if you look, and do full axial FOV recon
My TRO Conclusions

- TRO not useful for pts in the low-intermediate ACS risk population
  - Increased yield isn’t worth the cost
- TRO might be useful for pts in intermediate-high PE risk population
  - Many have intermediate-high likelihood of CAD
    - Watch out for incidental CAD diagnoses, which will lead to need for “rule-out ACS” testing
    - But ACS or dissection can give +D-dimer
- You won’t miss a dissection on any kind of CT
  - But, you might miss intramural hematoma
- Most patients will have triple negative studies
- Remember, the goal is to rule-out, not diagnose
AMI with CT Stenosis < 50%

- CT interpreted as 40% Cx stenosis
- Second troponin +, cath showed 99% OMI
- Evident in retrospect on CT
Comments

• Involve ED physicians and cardiologists in planning

• Have a plan with ED and cardiology buy-in
  • Disposition decisions
  • Discharge instructions

• Don’t waffle in your reports, they hate that
  • Having high quality studies is key
  • Be at the scanner for at least the first 100 studies
  • Don’t compromise on beta blockers and HR limits

• Have a system in place for patient follow-up
  • Convince yourself and others that it actually works
  • Demonstrate programs effectiveness to administrators
References

- Safety and Performance
References Cont’d

• Safety and Performance cont’d

• Health Services Analysis

• Alternative Diagnoses