Coronary CT Angiography in 2015: Where are we now, Where are we going?

Marc C. Newell, MD, FACC
Cardiologist
Minneapolis Heart Institute® at Abbott Northwestern Hospital

Monday, January 05, 2015, 7:00 – 8:00 AM

ANW Education Building, Watson Room

OBJECTIVES
At the completion of this activity, the participants should be able to:
1. Describe how Coronary CT Angiography is used in current cardiology practice.
2. Describe the breadth of indications for cardiac CT, including non-coronary uses.
3. Explain potential future directions in cardiac CT.

ACCREDITATION

Physicians: This activity has been planned and implemented in accordance with the Essential Areas and policies of the Accreditation Council for Continuing Medical Education (ACCME) through the joint sponsorship of Allina Health and Minneapolis Heart Institute Foundation. Allina Health is accredited by the ACCME to provide continuing medical education for physicians.

Allina Health designates this live activity for a maximum of 1.0 AMA PRA Category 1 Credit™. Physicians should only claim credit commensurate with the extent of their participation in the activity.

Nurses: This activity has been designed to meet the Minnesota Board of Nursing continuing education requirements for 1.2 hours of credit. However, the nurse is responsible for determining whether this activity meets the requirements for acceptable continuing education.

Others: Individuals representing other professional disciplines may submit course materials to their respective professional associations for 1.0 hours of continuing education credit.

DISCLOSURE STATEMENTS

Speaker(s): Dr. Newell has declared that he does not have a conflict of interest in making this presentation.

Planning Committee: Dr. Michael Miedema, and Eva Zewdie have declared that they do not have any conflicts of interest associated with the planning of this activity. Dr. Robert Schwartz declared the following relationships - stockholder: Cardiomind, Interface Biologics, Aritech, DSI/Transoma, InstyMeds, Intvalve, Medtronic, Osprey Medical, Stout Medical, Tricardia LLC, CoAptus Inc, Augustine Biomedical; scientific advisory board: Abbott Laboratories, Boston Scientific, MEDRAD Inc, Thomas, McNerney & Partners, Cardiomind, Interface Biologics; options: BackBeat Medical, BioHeart, CHF Solutions; speakers bureau: Vital Images; consultant: Edwards LifeSciences.
Cardiac CT in 2015: Where Are We Now? Where Are We Going?

Marc C. Newell, MD, FACC
Associate Director, Cardiac CT Imaging
Minneapolis Heart Institute

Disclosures

• Speaker’s Bureau: Siemens
Outline

• Cardiac CT in 2015
  – CT for chest pain/coronary disease
  – CT in the Emergency Department
  – CT for Structural Heart Disease and TAVR
  – CT for Prognosis
• Radiation reduction/Limitations
• Future Directions

Cardiac CT in 2015: Chest Pain

• Most common use is chest pain and CAD
• Increased “appropriate” uses with 2010 updated guidelines
• High negative predictive value
• Highly predictive of who needs coronary revascularization
• Prognosis and risk reclassification
• Highly accurate test
Multicenter MDCTA 64 Slice Trial: “Accuracy”

- Patient based analysis (n=230)
  - Sensitivity - 95%
  - Specificity - 83%
  - NPV - 99%
- Prevalence of obstructive CAD = 25%

Budoff MJ, et. al. JACC 2008;52:1724-1732

Multicenter Multivendor 64 Slice MDCTA Trial - Europe

- Patient based analysis (n=360)
  - Sensitivity - 99%
  - PPV - 86%
  - NPV - 97%
- Prevalence of obstructive CAD = 68%

Meijboom WB, et. al. JACC 2008;52:2135-2144
## Impact of MDT CA on Various Estimated Pre-test Probabilities of Significant CAD

### Risk Re-classification

48 yo female, atypical chest pain, high cholesterol = only risk factor…
Cardiac CT in 2015: CAD

- High negative predictive value
- Highly predictive of who needs coronary revascularization
- Prognosis and risk reclassification
- Highly accurate test
Cardiac CT in 2015: the Emergency Room

• What are we trying to achieve?
• Patient has no objective evidence of myocardial injury (no ST elevation on EKG, negative first cardiac enzyme)
• Is CAD present or not?
• Shorter time to a definitive diagnosis =
  – Save beds and save money
  – Save downstream testing

Goldstein and Raff et al

 Chest pain in the ER: CCTA vs standard of care (SOC) – overnight Observation unit, enzymes and nuclear stress test next day
 Clear improvements in time and money
  - Diagnostic time: 3.4 hours vs 15 hours (CT v SOC)
    - CT scanner available 7 AM-6 PM – time overnight included in cost and time data
  - $1,586 vs $1,872 (CT vs SOC)
  - Also, less need for repeat evaluations (2% v 7%) at 6 months
  - No MACE in either group at 6 months

CT STAT trial

- Multicenter trial in 699 ED chest pain patients from 16 EDs
- CCTA vs standard of care (serial cardiac enzymes and nuclear stress testing)
- Showed 54% reduction in time to diagnosis with CCTA vs standard of care
- 38% savings in cost ($2137 vs $3458)
- No difference in safety/MACE

CT STAT trial

- Randomized patients to CCTA vs Standard of Care after negative EKG and trop
- Length of stay (1° endpoint) = 7.6 hrs less in CCTA group
- Direct discharge from ED 47% v 12%
- No difference in cost of care

Hoffman et al NEJM 2012
• 2:1 randomization to CCTA vs Standard of Care (1370 patients total)
• No one discharged with normal CCTA had an event at one month
• CCTA group had:
  – Higher rate of d/c from ER: 50% vs 23%
  – Higher detection rate of CAD: 9% v 3.5%
  – Shorter length of stay: 18 v 24 hours

Coronary CT in the ER
• High rates of discharge from the ED
• Time savings
• Cost savings
• Low rates of downstream testing
Cardiac CT in 2015: Structural Heart Disease and TAVR


PARTNER trial: Inoperable Patients

PARTNER trial:
TAVR vs High Risk Surgery
Echo findings

Kodali SK, et al. NEJM 2012;366:1686-95
So what does CT have to do with TAVR?

• Assess aortic valve area and perimeter (annulus/valve sizing)
  – Height to coronary arteries
  – LVOT calcification
  – Ascending aortic size and calcification
• Access: peripheral, transapical, transaortic
• Peripheral and aortic anatomy
Transapical Access

- Prolonged post-op pain
- Increased intra and post-op bleeding

Transaortic Access

- >6 cm, Non-calcified puncture site
- Second Rt ICS
### Table 1. Thirty-Day Outcomes

<table>
<thead>
<tr>
<th></th>
<th>Transapical TAVR (n = 44)</th>
<th>Transapical TAVR (n = 70)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>VARC Combined Safety Endpoint</td>
<td>20%</td>
<td>29%</td>
<td>0.50</td>
</tr>
<tr>
<td>Mortality</td>
<td>14%</td>
<td>14%</td>
<td>1.00</td>
</tr>
<tr>
<td>Life-threatening and Disabling Bleeding</td>
<td>14%</td>
<td>13%</td>
<td>1.00</td>
</tr>
<tr>
<td>Major Bleeding</td>
<td>11%</td>
<td>28%</td>
<td>0.04</td>
</tr>
<tr>
<td>Total Bleeding and Vascular Complications</td>
<td>27%</td>
<td>48%</td>
<td>0.05</td>
</tr>
</tbody>
</table>

* VARC combined safety endpoint: all-cause mortality, major stroke, disabling bleeding, severe acute kidney injury, postprocedure MI, major vascular complication, and repeat procedure for valve-related dysfunction.

---

![Accurate CT Valve Area and Perimeters = Less Post-TAVR Aortic Insufficiency](image)

**Lardizabal JA, et al. JACC 2013;61:E1947**

**Kodali SK, et al. NEJM 2012:366:1686-95**
CT vs TEE for Annular Size

• Inappropriate valve sizing is the mechanism for most post-TAVR Aortic Insufficiency
• CT vs TEE
  – Larger valve in 33%, no change in 56%, smaller in 11%
  – If TEE “undersized”, mild AI in > 85%
  – Valve size and CT - good predictive value
  – CT measurement with good inter and intra-observer variability

Wood DA et al, JCCT 2012;6:406-414
Willson AB et al, JACC 2012;59:1287-94

<table>
<thead>
<tr>
<th>Aortic annulus diameter, mm</th>
<th>Distance to left main ostium, mm</th>
<th>Sinus of Valsalva width, mm</th>
<th>Sinus of Valsalva height, mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Edwards Sapien XT 23 mm</td>
<td>18-22</td>
<td>≥ 10</td>
<td></td>
</tr>
<tr>
<td>Edwards Sapien XT 26 mm</td>
<td>21-25</td>
<td>≥ 10</td>
<td></td>
</tr>
<tr>
<td>Edwards Sapien XT 29 mm</td>
<td>24-37</td>
<td>≥ 10</td>
<td></td>
</tr>
<tr>
<td>MedtronicCoreValve 26 mm</td>
<td>20-23</td>
<td>≤ 40</td>
<td>≥ 27</td>
</tr>
<tr>
<td>Medtronic CoreValve 29 mm</td>
<td>23-27</td>
<td>≤ 43</td>
<td>≥ 20</td>
</tr>
<tr>
<td>Medtronic CoreValve 31 mm</td>
<td>26-30</td>
<td>≤ 43</td>
<td>≥ 20</td>
</tr>
</tbody>
</table>

TAVI, transcatheter aortic valve implantation; TAVR, transcatheter aortic valve replacement.
Annulus in Systole is Preferred

Systole - 20% of R-R

Diastole - 75% of R-R

Annulus to RCA – 16 mm

Annulus to LM – 13 mm

Trileaflet Ao Valve – 25 x 26 mm

5.47 cm² is 17% < 29 mm
CT in Structural Heart Disease: Case: Early Acute CHF

- 71 yo man had a # 23 St. Jude Trifecta valve placed for severe AS two years before
- Progressive SOB with CHF within one year post-op
Coronary CT in 2015: Prognosis

- Confirm registry of 23,854 patients
  - No known CAD
  - Primary endpoint - time to death from all causes
  - Mean f/u 2.3 +/- 1.1 years

Min et al JACC.
High Risk Plaque Assessment

• Unique to CTA (Non-invasive)
  – Highly predictive of future events
  – Non-invasive plaque assessment
• Recent meta-analysis showed plaque quantification is as good as IVUS*

*JCCT 2013

Figure 2: Case I: With Acute Coronary Syndrome

The CT characteristics of a culprit lesion in a 50-year-old male patient presenting with acute coronary syndrome. (A) Volume rendering, (B) Coronal MPR, (C) Magnified view of the region of interest from (C), (D) Coronary angiogram. The white arrow in (A) shows the site of luminal obstruction or culprit lesion. As shown by the iodine-poor lesions at 2 sites on the culprit lesions (C), the lesions are positively remodeled as compared with the normal coronary segment proximal to the lesions (detected by unenhanced scans). De novo cases in this patient were LAD and diabetic statin effects (as assessed by IVUS <0.35 mm thick). The 3D-CT PVD ≤50% B,target lesion plaque (plaque area) CT = computed tomography, LAD = left anterior descending artery, MPR = multiplane reconstruction, IVUS = intravascular ultrasound.
Plaque Characteristics in Acute Coronary Syndrome versus Stable Angina Pectoris


- Positive Remodeling
  - 87% (p<0.001)
  - 12%
- NCP < 30HU
  - 79% (p<0.001)
  - 9%
- 30HU < NCP < 150HU
  - 100% (p<0.0005)
  - 63%
- Spotty Calcification
  - 21%
- Large Calcification
  - 22%
- 55%


High-Risk Atherosclerotic Plaque Characteristics

- 2 features assessed by CTA:
  1) Low Attenuation Plaque
  2) Positive Remodeling

- 40-fold higher event rates if both features present versus neither

Motoyama, JACC 2009
Cardiac CT in 2015: Other niches

- Pre-valve surgery
- Re-op assessment of LIMA
- Chest/vascular anatomy prior to:
  - minimally invasive cardiac surgery
  - LVAD/Transplant

- EP:
  - Pre-procedural planning pulmonary veins
  - Left atrial appendage assessment

- Vascular patients
  - Claudication, abnormal ABIs
  - After endovascular stent grafting
Barriers to Cardiac CT in 2015

- Experience
- Renal impairment
- Guideline/payment support
  - improving
- Arrhythmia
  - Radiation

Relative Radiation Doses: Medical Imaging

<table>
<thead>
<tr>
<th>Type</th>
<th>Dose mSv</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yearly ambient exposure (U.S.)</td>
<td>3.0²</td>
</tr>
<tr>
<td>Chest PA and Lat</td>
<td>0.04</td>
</tr>
<tr>
<td>Mammogram</td>
<td>0.7</td>
</tr>
<tr>
<td>CT Chest (non-gated)</td>
<td>7.8 to 12</td>
</tr>
<tr>
<td>CT Abdomen</td>
<td>7.6 to 12</td>
</tr>
<tr>
<td>Diagnostic CA</td>
<td>2.3 to 5.6</td>
</tr>
<tr>
<td>*Calcium score (prospective)</td>
<td>0.3 to 1</td>
</tr>
</tbody>
</table>

*MHIF experience
²Recent estimates suggest this may have doubled in the past decade
## Radiation Doses in Cardiology

<table>
<thead>
<tr>
<th>Type</th>
<th>Dose mSV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stress-rest Tc99 (Sestamibi)</td>
<td>11</td>
</tr>
<tr>
<td>Stress-rest Tc99 (Tetrofosmin)</td>
<td>9</td>
</tr>
<tr>
<td>Stress-rest TI-201 (Thallium)</td>
<td>17</td>
</tr>
<tr>
<td>Dual Isotope (stress-rest)</td>
<td>24</td>
</tr>
<tr>
<td>*CCTA (pulsed, retrospective)</td>
<td>12-18*</td>
</tr>
<tr>
<td>*CCTA (MHI in 2009, 660 pts)</td>
<td>3.6</td>
</tr>
<tr>
<td>*“Flash” mode/scanner</td>
<td>0.3-1.2</td>
</tr>
</tbody>
</table>


*Prior to modern adjustments

---

Can we do full Coronary CT with low radiation?

mSv dose 0.45
Radiation Reduction Techniques

- Many trials have shown dramatic radiation reductions (Protection, MI, Romicat)
- Many generations of scanners now –
  - faster table pitch = shorter scan times
  - Improved detectors
- Limiting kV used – ↓ radiation exponentially
- Iterative Reconstruction
  - improve scan quality post scan

Future Directions in Cardiac CT

- Using CT’s strengths:
  - Cardiac CT for screening (asymptomatic)
  - Increased clinical use in of CT in the Affordable Care world…
    • Save time (shorter stays, less observation pts)
    • Save money
    • Save downstream testing
- Addressing CT’s weaknesses:
  - FFR CT
  - CT Perfusion
Ideal Characteristics of a Screening Test

- Accurate
- Predictive
- Minimize (unnecessary) “downstream” testing
- Cheap
- Low Risk
- Provide “actionable” information
Screening: Can We Impact Risk?

- Plaque (and patient) risk assessment
- Enhanced Appropriate Pharmacology
- Lifestyle Intervention
SCOUT Study – STATIN USE

- Computational flow models based on flow dynamics and flight
- Assess the physiologic significance of a moderate (50-70%) stenosis seen on Coronary CTA

FFR CT

- Computational flow models based on flight
- Assess the physiologic significance of a moderate (50-70%) stenosis seen on Coronary CTA

Cardiovascular Grand Rounds 1/5/15
Minneapolis Heart Institute® at Abbott Northwestern Hospital
Rationale for FFR CT

- CCTA’s weakness is with specificity and PPV of intermediate stenoses
- QCA and CCTA highly correlated
  - Stenoses > 50% predict ischemia < ½ lesions
- DEFER, FAME I, II – lessen events with targeted PCI based on invasive FFR
  - Better than angio guided PCI or best med treatment

Pijls NH et al. JACC 2007;49:2105-2111
Tonino PA, et al. NEJM 2009;360:213-224

Per-Patient Diagnostic Performance for Intermediate Stenoses by CT (30-70%)
FFR-CT NXT Trial

- Patients (n=251, 484 vessels) with 30 to 70% stenoses
- FFR-CT
  - More careful requirements for CT image quality
  - Improved technical and physiologic modeling – based on retrospective learning from prior trials
- Invasive FFR on all vessels
CT Perfusion

- CCTA major limitation is a low PPV
  - Unknown physiologic significance of intermediate lesions
- Combine CT Perfusion with CTA
  - Intermediate to high pre-test risk
  - Contrast properties similar to gadolinium
  - Total contrast dose ~ 130 to 150 ml

Techasith T, et al. JACC Img 2011;4:905-916
Thank You!

• Marc Newell, MD, FACC
• marc.newell@allina.com