CT: Feasibility and Accuracy

Wm. Guy Weigold, MD
Director of Cardiac CT
MedStar Heart Institute
MedStar Washington Hospital Center
Washington, DC
Coronary CTA in 2013

Using modern scanners, coronary CTA should be technically feasible in a wide range of patients with a minimum of radiation and contrast.
Prospective ECG-Triggered Cardiac CT
Prospective ECG-Triggered Axial Scan

Step & Shoot Cardiac scan
Prospective CCT

- **X-ray tube is OFF during most of the scan!**
- **Gantry rotation speed more important than in helical CT**
  - Helical cardiac CT uses “oversampling” of data, to allow multi-cycle reconstruction
  - “Virtual” temporal resolution may be faster than gantry speed
  - In sequential (prospective) cardiac CT, there is no oversampling
  - Temporal resolution is entirely dependent on gantry speed
Same Image Quality; Much Lower Dose

1-4 mSv
(vs. 12-18 mSv for helical cardiac CT and 6-8 mSv for standard chest CT)
Key Elements of Prospective CT

1. Tube Power
2. Coverage
3. Gantry Speed
Key #

1: X-ray tube

- Spiral Groove Bearing
- Double support for 220rpm
- 0.27sec

- Flat Field Emitter
- Higher flux rate and focal spot integrity

- Segmented Anode
- 120kW instantaneous power

- Key for prospective CT
Tube Power Overcomes Obesity

Step & Shoot Scan

- Mrs G - 55 y.o. woman with chest pain
- 5’8” (1.7 m) 285 lb (130 kg) BMI 43.4
- 80 mL contrast
- 120 kV 993 mA 560-deg sc angle 420 mAs
- HR 59
- CTDI 38.6 DLP 601.1 Eff Dose 8.4 mSv
Step & Shoot Coronary CTA

LAD  Cx  RCA
Dose Only Where Needed

*Helical Dynamic Collimation to Reduce Overscanning*

Without HD Collimator

Unused dose

With HD Collimator

Unused dose cut by rolling collimator

Courtesy Mani Vembar, PhD
Key #2: Detectors & Coverage

16x16 elements

Nano-Panel™

Detector module
* Expandable to 16 cm

Scintillator
Photodiode
Electronics

Detectors are 0.625 mm in width

128 rows x 0.625 mm = 80 mm of coverage
Increasing Detector Rows = Increased Z-Axis Coverage

- **Increased z-axis coverage = shorter scan duration**
  - Shorter breath holds
  - Fewer heart beats
  - Less contrast
Coverage

- Larger coverage:
  - 80 mm
  - For a typical cardiac scan (120 mm)
    - Two axial shots
    - 3 Heart beats
    - 4-5 second scans
- Less vulnerability to irregularity / arrhythmia
- More reliable performance in scan after scan
Dose Only When Needed

Adaptive Axial Collimation

Key #3: Gantry Speed

500 ms
420 ms
370 ms
330 ms
270 ms
Benchmark Speed

- **Air Bearing System**
  - Completely new and innovative breakthrough technology

- 270 msec per rotation

- 220 rpm
  - vs. 180 rpm at 330 ms/rotation (30%)

- Preserved geometric integrity
High speed = Better temporal resolution

250 ms  210 ms  165 ms
Step & Shoot Cardiac CT
Heart Rate 79 bpm
Step & Shoot Cardiac CT
Heart Rate 79 bpm
Keys to Prospective Cardiac CT

- The best prospective cardiac CT will be performed by a scanner that offers the combination of...
  - wide detector coverage and
  - high-speed gantry rotation and
  - strong x-ray tube power

- This permits reliable helical and prospective (step & shoot) cardiac scanning and delivery of high quality images with only a minimum of contrast and radiation exposure
100 kV Scanning Reduces Radiation Exposure
Step & Shoot - Radiation Dose

- Mrs. F 61 y.o. woman
- Dyslipidemia and family history of CAD
- 5’1” 126 lb (57 kg)
- **100 kV** 709 mA 560-deg sc angle 300 mAs
Step & Shoot Coronary CTA

LAD
Cx
RCA
2D Map & Dose

$185 \text{ mGy} = 2.6 \text{ mSv}$
Step & Shoot CT
Low Radiation Dose

• 27 y.o. woman (60 kg) with acute episode of dyspnea

• Evaluation at outside hospital
  - CT scan & echo: cardiomyopathy; no pulmonary embolus

• Referred to coronary CTA
Step & Shoot Cardiac CT
iCT
100 kV
200 mAs
1.4 mSv
Iterative Image Reconstruction

- First major update to image reconstruction method since inception of CT in 1970’s
- Driven by desire to minimize radiation exposure
- Advanced reconstruction algorithm makes multiple “passes”
- Results in lower image noise
- Permits scanning with lower x-ray exposure while preserving image quality
How does iDose\textsuperscript{4} work?

**Projection space (raw data)**
- Each projection examined for points likely caused by noisy measurements
- Iterative diffusion process wherein noisy data is penalized while edges are preserved
- Signal streaking & bias errors are prevented

**Image space (pixels)**
- Structural & data-dependent noise models used to iteratively eliminate quantum image noise while preserving underlying edges associated with the anatomic model
- Multi-frequency noise removal maintains noise power spectrum

- **Acquisition**
  - Data variation analysis
  - Update projections

- **Model selection**
  - Noise Model
  - Structured Model Based on local anatomy
  - Multi-frequency model of noise removal

- **Optimized Model?**
  - Y
    - (Noise Optimized) Images
  - N
    - Update projections

- **Structured Model Based on local anatomy**
Low Dose Imaging on Brilliance iCT

Step & Shoot Cardiac using iDose⁴

100 kVp, 150 mAs, 13.4 cm coverage
DLP: 95.2, estimated radiation dose: 1.3 mSv

Courtesy: Dr. Guy Weigold, Washington Hospital Center
Blooming Artifact Reduction via iDose\textsuperscript{4}
Additive Dose Sparing Technology

Minimize scan range
Lower tube voltage
Prospective, sequential scanning
Lower tube current + iterative reconstruction

Routine Cardiac CT with <1 mSv
Cardiac CT using < 1 mSv
Cardiac CT using < 1 mSv
Low Dose Imaging on Brilliance iCT

*Step & Shoot Cardiac using iDose⁴*

100 kVp, 100 mAs, 10.9 cm coverage
DLP: 64, estimated radiation dose: 0.9 mSv

Courtesy: Seirei Yokohama Hospital, Japan
Low Dose Imaging on Brilliance iCT

*Step & Shoot Cardiac using iDose*4

100 kVp, 75 mAs, 10.9 cm coverage
DLP: 40.9, estimated radiation dose: 0.5 mSv

**Courtesy:** Dr. Harvey Hecht Lenox Hill Hospital, New York
Key Elements of High Speed, Low Dose Cardiac CT

1. Tube Power
2. Coverage
3. Gantry Speed

Essential Requirements for Reliable Prospective Scanning

4. Dose Sparing Hardware
5. Iterative Reconstruction

Additional Requirements for Further Dose Reduction
IMPLICATIONS OF LOW DOSE CT
## Scan Characteristics and Results
(n=235)

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<td>Adverse event</td>
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CT-STAT: Most patients don’t have significant disease

- **No significant stenosis**: 297/361 (82%) pts
  - 262 (72.6%) discharged
  - No (0/297) ACS at 6 months f/u

- **Severe stenosis**: 27 (8%) pts
  - ICA in 24 → revasc in 13 (54%) (9 PCI, 4 CABG)

- **Borderine stenosis**: 23 (6%) pts

- **CT uninterpretable**: 14 (4%) cases
  - MPI in these 37
Future Application - Triple Rule Out
Future Application - Scar Imaging
Future Application - Dynamic Perfusion Imaging
Flexibility Will Be Key

With new applications & increasing role of CT, becomes even more important for scanners to be flexible in order to handle ALL clinical scenarios:

- Not just manage high heart rates for coronary imaging, but also wide coverage for triple rule out and whole heart imaging
- Not just wide coverage but also high speed
- High tube power for best step and shoot and obese pts