Dose Concerns and Reduction Strategies in Cardiothoracic CTA

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Radiation exposure concerns
- Medical radiation exposure x3 1994-2006
- Early age exposure ↑ lifetime mortality risk
- RR for breast cancer of up to 4.2% per single cardiothoracic CTA

Outline
- Options for dose reduction
- Practical recommendations
How to reduce radiation dose?

**CTPA and CCTA**
- Adherence to appropriate indications
- Anatomical scan coverage
- Pitch
- Tube settings modulation
- Noise reduction technique
- Prospective vs. Retrospective gating
- New techniques

**CTPA Scan coverage (Z) optimization**
- Radiation dose saving of ~40%

**CCTA Scan coverage (Z) optimization**
- 25 cm
- 15 cm
- 12 - 14 cm
- 1 cm length ~ 50-100 mGy.cm

**Pitch: CTPA**
- Pitch = Table movement/Beam width
- CTDI_{vol} = CTDI_{w} x 1/Pitch
- ↑ Pitch = ↓ Dose
- Linear reverse relationship:
  - ↑ Pitch by 25% ↓ Dose by 25%

**Pitch: CCTA**
- Low pitch (0.2) - to avoid gaps
- Pitch is usually fixed
- Newer scanners allow higher pitch with higher HR (up to 0.4)

**CTPA Tube settings:**
- Tube potential - kVp
- Tube current x time product - mAs
- Tube current modulation:
  - Automatic Exposure Control - AEC
**CTPA Tube settings: kVp**

- Radiation exposure is: **Exponentially** proportional to kVp
- Low photon attenuation in the thorax
- ↓ kVp → ↑ photon attenuation
  - ↑ contrast
  - ↓ noise

**Why is low kVp better?**

- kV beam is polychromatic
- Lower kV beam has greater proportion of beam at k-edge of iodinated contrast (33.2 keV)
- ↑ Attenuation with same amount of contrast
- 140 kVp → 120 kVp: ↓ dose by 30-35%

**Lower kVp - Higher HU**

Schueller-Weidekamm et al. Radiology 2000

![Graph showing average CT numbers (HU) for different kVp settings.](image)

**Lower kVp – Lower radiation dose**

- **120 kVp**
  - CTDI 31 mGy
  - ED 2.5 mSv
- **100 kVp**
  - CTDI 18 mGy
  - ED 1.4 mSv (44%)
- **80 kVp**
  - < 75 kg, ED < 1 mSv

Heyer et al. Radiology 2007

**CTPA Tube Settings: mAs**

- Radiation – in linear proportion to mAs
- Decrease in mAs to 40 – 90 mAs
- **1.0 mAs/kg** for chest CT

Tack et al. Radiology 2005

**CTPA: Tube current modulation:**

- ↓ mAs for regions of lower attenuation
- ↑ mAs for regions of higher attenuation
- Automatic exposure control (AEC)
- Tube current adjustable from 20-400 mAs
**Tube current modulated chest CT**

Tube current modulated in 3 dimensions: X, Y, Z

- Z – longitudinal
- X, Y – angular
- X, Y, Z – combined

Patient position – isocentric

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**Combined X, Y, and Z modulation**

![Graph](image)

**CTPA : Partial tube modulation**

![Image](image)

**Breast, Lung, and Pelvic Organ Radiation – Phantom study**

![Graph](image)

**CTPW Tube settings recommendations:**

- 100 kVp in normal - 90 kVp in slim patients
- 120-140 kVp only in patients with BMI > 30
- Automatic dose modulation imperative
- CT scanner dose report

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**CCTA Tube settings: kVp**

- <90 kg or BMI <30 kg/m² – 100 kV
- >90 kg or BMI >30 kg/m² – 120 kV
- Severely obese >120 kV

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**Breast - ↓ 28 mGy to 4.9 mGy**

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**Bankier et al. J Thorac Imag 2010**

**Duan X et al. AJR 2011**

**Litmanovich et al. AJR. 2011**

**McCollough et al. Radiographics 2006**

**Bishoff et al. JACC 2009**
**Tube settings: CCTA**
- Comparison of 80 vs. 100 kVp

80 kVp, BMI < 25 kg/m²

LaBounty et al. AJR 2011

**CCTA Tube settings: mAs**
1. Anatomy-based tube current adaptation
2. ECG-based tube current modulation
   - Retrospective gating
   - Prospective gating
   - Prospective gating with no padding

**CCTA: Retrospective ECG gating**

Preferred for pts with ↑ HR/irregular heart rhythms

Small et al. J Nucl Cardiol 2011

**CCTA: Prospective ECG gating**

Preferred for pts with regular HR < 65 bpm

Small et al. J Nucl Cardiol 2011

**CCTA: Prospective ECG gating**

Padding: margins of diastasis
Reduced padding reduces beam on time

Preferred for pts with regular HR < 65 bpm

Small et al. J Nucl Cardiol 2011

**Prospective vs. Retrospective gating: Image quality**

Pro

Retro

Blachoff et al. AJR 2010
Prospective vs. Retrospective gating:
Radiation considerations

Bischoff et al. AJR 2010
Shuman et al. Radiology 2008

77% in radiation dose
BUT cannot be applied with irregular heart rate!

Dual-Source CT

Fast non-overlapping spiral data acquisition
Pitch 3.4
Up to 60% dose reduction in patients with HR<60

Volumetric CT

- 320 -row MDCT scanner
- Heart image – in one rotation
- Phantom experiment – up to 91% decrease in radiation dose

Einstein et al. Radiology 2010

Noise Reduction Techniques

Dose reduction → increase in image noise
Noise reduction techniques → indirect contributor to dose reduction efforts

Post processing techniques
Dedicated post processing software
Noise reduction filters

Pre processing techniques
ASIR, IRIS, MBIR

Iterative Reconstruction Algorithm

- Alternative reconstruction algorithm
- Used in conjunction with Filtered Back Projection
- Selectively identifies and subtracts noise from image
- 30% - 40% dose saving

Bankier et al. J Thorac Imag 2010
Hara et al. AJR 2009

Iterative Reconstruction Algorithm
CCTA

- Coronary CTA : decrease in dose by up to 44%:
  ERASIR Study

100 kV, 325 mA, no padding, 14cm: 0.56 mSv
Leipsic et al. AJR 2010
Radiation exposure in CCTA: Evolution over time

Small et al. J Nucl Cardiol 2011

Each of the following strategies is associated with increased radiation exposure EXCEPT

- 1. Retrospective ECG gating.
- 2. Decreased pitch.
- 3. Application of novel reconstruction algorithms.
- 4. Decreased noise index.

Dose Registries

- American College of Radiology
- Protection1: 50 sites, >1960 exams
- ACIC: Advanced CV Imaging Consortium

Hausleiter et al. JAMA 2009

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- 1. Retrospective ECG gating
- 2. Decreased pitch
- 3. Application of novel reconstruction algorithms
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Bankier et al. J Thorac Imag 2010

Outline

- Radiation exposure concerns
- Assessment of radiation dose
- Options for dose reduction
- Practical recommendations

Practical recommendations

CTPA and CCTA

- Read the CT scanner dose reports
- Use reference CTDIvol
- Choose appropriate kVp
- Iterative Reconstruction when available
- Prevent overscanning
- Personalizing study for each patient

Bankier et al. J Thorac Imag 2010
**CTPA Practical recommendations**

- AEC always “ON”
- Gradually decrease index of image quality
- Smoother reconstruction algorithm

Bankier et al. J Thorac Imag 2010

**CCTA Practical recommendations**

- Prospective ECG gating  HR<65
- Retrospective: only with tube current modulation
- kVp as low as reasonably possible

Halliburton et al. J SCCT 2011

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**Summary**

- Assessment of radiation dose
- Options for dose reduction
- Practical recommendations

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