Choosing CT Scan Parameters
Cardiac CT, Perfusion CT

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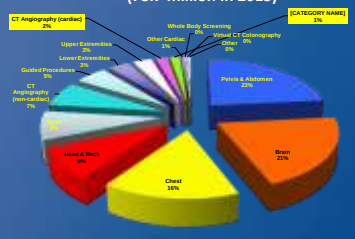
Introduction

- Cardiac CT and Perfusion CT are deemed high dose CT procedures
- However, from past few years, radiation doses have trended downward
- Choosing appropriate type of scan parameters are contributing towards this downward trend

Categories of CT procedures
(78.7 million in 2015)



HCAP: ~76% of all CT procedures IMV 2015

Scan Parameters impacting Dose and Image Quality in CT

Primary Factors

- Tube Current (mA)
- Tube Voltage (kV)
- Scan Time
- Pitch
- Scan Acquisition Type

Secondary Factors

- Scan Field of View (SFOV)
- Display Field of View (DFOV)
- Beam Collimation
- Reconstructed Slice Width
- Reconstruction Interval
- Reconstruction Algorithms

Other Factors

- Patient Size
- Patient Motion
- Geometry and Detector Efficiency
- Training and experience

Mahesh M., MDCT Physics: The Basics..., Lippincott, 2009

Cardiac CT

Cardiac CT

Prominent scan types

- Calcium Scoring Studies
- CT Angiography Studies
- Cardiac CT prior to EP Ablation procedures

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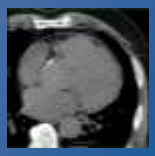
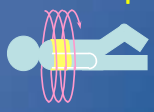
Tube Current (vary with clinical indications)



Calcium Score Image
Range: 25 to 200 mA

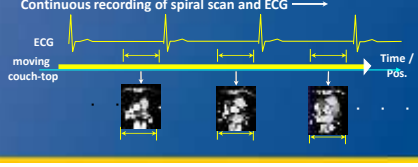
CTA Image
Range: 200 to 800 mA

Retrospective ECG Gating



Temporal Resolution
Radiation dose higher than prospective triggering

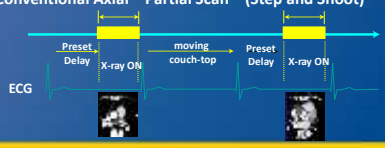
Continuous recording of spiral scan and ECG ⟶



Prospective ECG Triggering

Temporal resolution
Radiation dose minimized
Limited data set

Conventional Axial " Partial Scan " (Step and Shoot)



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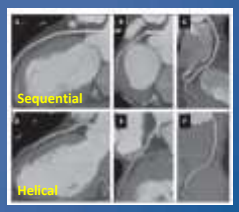
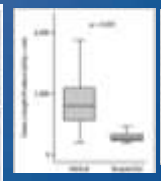
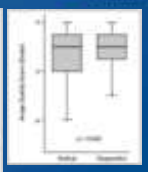
CTA Dose: Prospective vs Retrospective







Helical mode: 11.2 mSv
Sequential mode: 3.6 mSv

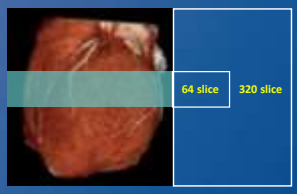
PROTECTION I study, AJR, 2010

Motivation for advancement in CT technology

Goal

- To image entire heart in single CT gantry rotation
  - Achieved by wide-detector CT systems
- To image entire heart in a single heart beat
  - Achieved with high-pitch scan using dual source CT

Scan coverage - 320 vs 64 slice MDCT



Toshiba
Aquillion 64 - 32 mm beam width
Aquillion One - 320 slice MDCT - 160 mm beam width

MDCT Physics: The Basics..., Lippincott, 2009

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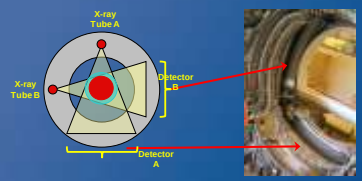
Dual Source CT



Definition – FLASH

2nd Detector set still smaller than 1st but larger than Definition

SFOV: 1st detector – 50 cm, 2nd detector – 34 cm

* Siemens

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Single Source vs Dual Source CT*

64 Slice MDCT ~190 ms

DSCT ~ 90 ms

180° Data Acquisition 90° Data Acquisition per tube

Temporal resolution: ~ 1/3rd to 1/4th of gantry rotation time

* Siemens

High Pitch Cardiac CT Scan with DSCT

- Interleaved spiral path from dual source is used in image reconstruction
- High-pitch (>3) scans enables data acquisition within single heartbeat
- High demand on patient selection (< 60 bpm desired)

* Achenbach S, JCCT, 3:117-121, 2009

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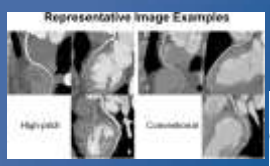
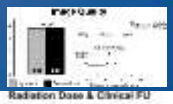
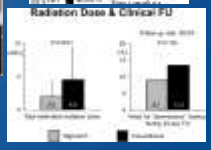
CTA Dose: Conventional vs High Pitch







Conventional: 4.7 ± 4.8 mSv
High pitch (DSCT): 2.0 ± 2.4 mSv

PROTECTION IV study, JCCT, 2015

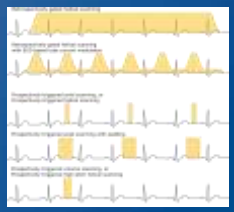
CT Dose Modulation

Spatial Dose Modulation

Temporal Dose Modulation

Temporal Dose Modulation for coronary CT Angiography

- Constant tube current through entire R-R cycle can be modulated
- Tube current is lowered outside diastolic region enabling dose reduction during cardiac CT



Cardiac CT: Take Home Points

- Calcium scoring studies are done mostly with fixed techniques – low tube current - lower radiation dose
- Cardiac CT Angiography studies are increasingly prospective triggered acquisition
- Also, temporal dose modulation, lower tube voltage along with iterative reconstruction techniques all are aiding in lowering dose in CT Angiography studies

Perfusion CT

What is CT Perfusion?

- CT Perfusion is an imaging procedure that allows functional evaluation of tissue vascularity
- Perfusion CT is based on temporal changes in tissue attenuation after intravenous administration of iodinated contrast material
- Post intravenous injection of iodine contrast material, tissue enhancement is evaluated based on its distribution in intravascular or extravascular compartment

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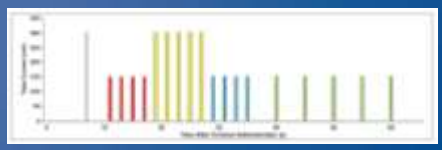
How is CT Perfusion done?

- After injecting iodine contrast materials, series of CT scans are done over same region
- Repeated acquisitions of volume of interest during first pass of contrast material is obtained – can last approximately 1 or 2 min
- Followed by CT acquisition of delayed phases – can last from 2 to 10 minutes

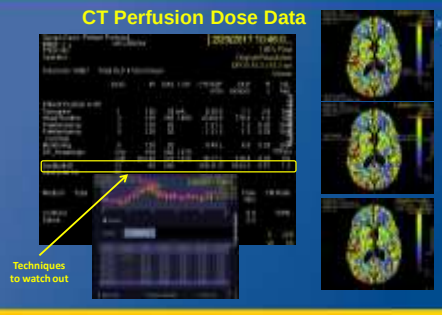
Brain Perfusion CT Acquisitions



White – Mask
Red – early arterial phase, Yellow – peak arterial phase
Blue – late arterial phase, Green – venous phase

Cros M, et al., AJR 2016; 206: 129-135

CT Perfusion Dose Data



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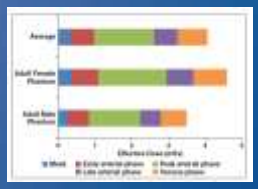
Effective Dose: Brain Perfusion CT

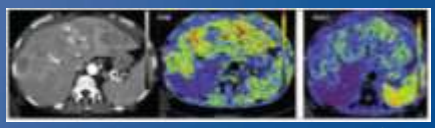


4 mSv for perfusion CT of brain

23 to 26 mSv for perfusion CT body protocols

Cros M, et al., AJR 2016; 206: 129-135

CT Perfusion in Oncology



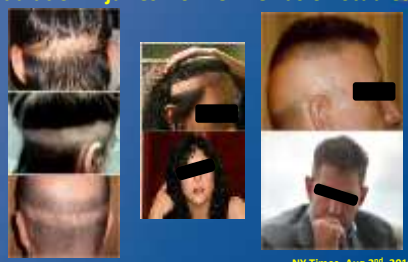
Conventional CT before Therapy

Hepatic Perfusion before Therapy

Hepatic Perfusion 4 hours after Therapy

AJR: 200, 2013

Radiation Injuries from CT Perfusion Studies



NY Times, Aug 2nd, 2010

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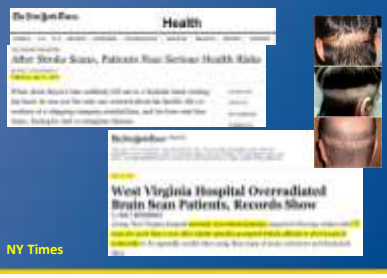
Radiation Injuries in CT – Rare but possible!



NY Times

CT Perfusion: Take Home Points

- Watch out for skin dose exceeding threshold to cause deterministic effects due to repeat scans
- Using lower tube voltage 100 kV or 80 kV during contiguous acquisition are critical to reduce skin injuries
- $CTDI_{vol}$ displayed at end of CT exam can be used as conservative predictor of peak skin dose for most CT perfusion studies

Iterative Reconstruction

- Objective is to enable user to acquire CT data at low dose and improve image quality with iterative process
- Most iterative reconstruction algorithms due to manufacturer proprietaries act as 'BLACK BOX'

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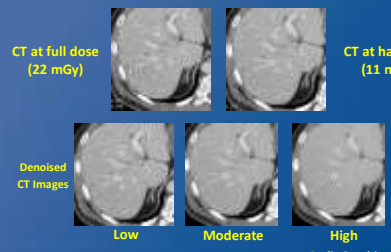
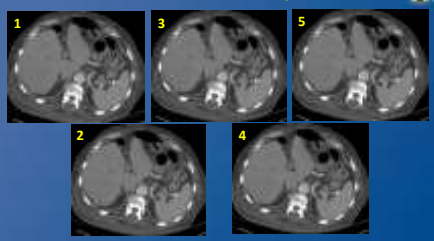
Effect of Iterative Reconstruction



RadioGraphics, 34, 849-862, 2014

Iterative Reconstruction Techniques: SAFIRE 1 to 5



Increasing from 1 to 5 results in progressively less noise, but a more opaque appearance

Iterative Reconstruction:
Degradation of CT low contrast at reduced dose

- Dose reductions of 25%–50%
  - Degraded low-contrast spatial resolution compared with FBP even with use of IR
  - Ability to visualize low-contrast rods in ACR CT accreditation phantom can be lost
- Use of IR techniques at decreased radiation dose levels may degrade diagnostic performance

McCollough CH, et al., Radiology, 2015

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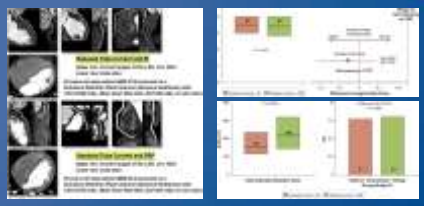
CTA Dose: Impact of IR

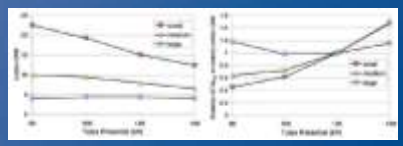


Reduced mA + IR: 2.2 (1.6 – 3.3) mSv
Standard mA + FBP: 3.1 (2.0 – 4.5) mSv

PROTECTION V study, JACC, 2015

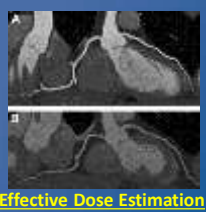
Tube Voltage Modulation

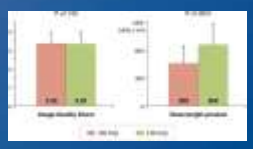
- Lower tube voltage improves image contrast and reduce dose
- As tube voltage decreases, tube current may have to be increased to maintain image noise



Radiology 2012; 264(2): :567-580

Influence of Tube Voltage on CTA Dose





Effective Dose Estimation
A - 100 kV: 8.4 ± 3.6 mSv
B - 120 kV: 12.2 ± 4.4 mSv

PROTECTION II study, JACC, 2010

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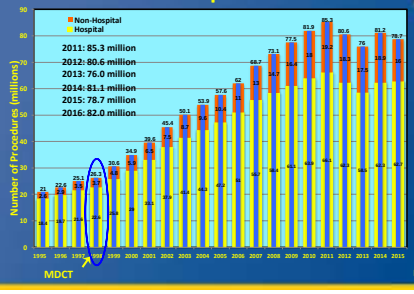
Conclusions

- Cardiac CT imaging has been the driving force behind many technical advances in MDCT
- Understanding and choosing appropriate scan parameters is key to deliver optimal dose in cardiac CT or perfusion CT

Number of CT procedures in US



IMV Benchmark 2016

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