Dose Reduction Strategies in CT

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Radiation Injuries in CT – Rare but possible!

The New York Times

After Stroke Scans, Patients Face Serious Health Risks

When Alain Rey’s arm suddenly fell out in a freakish band circling his head, he was not the only one worried about his health. His co-workers at a shipping company avoided him, and his boss sent him home, fearing he had a contagious disease.

West Virginia Hospital Overirradiated Brain Scan Patients, Records Show

A large West Virginia hospital seriously overirradiated patients suspected of having strokes with CT scans for more than a year after similar episodes prompted federal officials to alert hospitals nationwide, to be especially careful when using those types of scans, interviews and documents show.

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Recurrent CT, Cumulative Dose and Cancer Risks

- 22 year study - 31463 patients
- CT: 22 scans in 5%, 38 scans in 1%
- Cumulative Dose:
  - 15% received >100 mSv
  - 4% over 250 mSv
  - 1% over 399 mSv
- CT abdomen and Pelvis is most common repeat exam among patients

Sodickson, A. et al. Radiology 2009;251:175-184
Introduction

• Optimization of MDCT protocols requires thorough understanding of all technical aspects of CT
  - Relevant scan parameters
  - Dose reduction techniques
  - New technological advances
• Scan and technical parameters are to be tailored to
  - Patient size
  - Body region
  - Clinical questions
• Diagnostic image quality should not be compromised in the effort of reducing dose

Radiation Dose Reduction Strategies

• Optimal tube current (mA) selection
  - Dose modulation strategies
• Reduce tube voltage in suitable patients
• Minimize scan range
• Dynamic collimation
• In Cardiac Imaging
  - ECG gated tube current modulation
  - Prospectively ECG-triggered axial scanning
• Iterative Reconstruction
• Dose Reports
• Dose Check®...
Factors affecting Radiation Dose and Image Quality

<table>
<thead>
<tr>
<th>Primary Factors</th>
<th>Secondary Factors</th>
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<tbody>
<tr>
<td>• Tube Current (mA)</td>
<td>• Scan Field of View (SFOV)</td>
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<tr>
<td>• Tube Voltage (kVp)</td>
<td>• Display Field of View (DFOV)</td>
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<tr>
<td>• Scan Time</td>
<td>• Beam Collimation</td>
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<tr>
<td>• Pitch</td>
<td>• Reconstructed Slice Width</td>
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<tr>
<td>• Scan Acquisition Type</td>
<td>• Reconstruction Interval</td>
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<td>• Reconstruction Algorithms</td>
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<table>
<thead>
<tr>
<th>Other Factors</th>
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<tbody>
<tr>
<td>• Patient Size</td>
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<tr>
<td>• Scan Length</td>
</tr>
<tr>
<td>• Patient Motion</td>
</tr>
<tr>
<td>• Geometry and Detector Efficiency</td>
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<td>• Training and experience</td>
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**CT Dose Modulation**
Automatic Tube Current Modulation (ATCM)

• Tube current modulation available:
  - Smart mA (GE), Care Dose (Siemens)
  - Sure Exposure (Toshiba), Z-DOM (Philips)

• For Pediatric CT scans, requires special attention such as
  - Positioning of patients (isocenter)
  - User defined parameters (reference mAs or noise index, Anatomical region, etc…)

• Need to analyze whether ATCM is really effective or can dose reduction be simply achieved by modifying scan parameters (mA or kVp) manually

Tube Current: Radiation Dose vs Image Noise

• Renal Cyst (white arrow) observed at all 4 radiation dose levels

• Conspicuity of small liver vessels is compromised at 50 mAs

JACR, 8(5): 369-372, 2011
CT dose reduction by Tube Voltage modulation

- Modulating tube voltage based on the patient size
- Lower tube voltage improves image contrast and reduce dose
- As tube voltage decreases, tube current is increased to maintain image noise
- Specially effective during CT Angiography procedures
- New feature

**CT Dose Reduction by Tube Voltage Modulation**

![Graphs showing CT dose reduction by tube voltage modulation](image)

*Fig. 3. (A) Graph of the CT number of a 2% iodine solution for small, medium, and large phantoms at various x-ray tube potentials. (B) Graph of noise (standard deviation of CT numbers within the water background) in images of small, medium, and large phantoms at different tube potentials. (C) Graph of the contrast-to-noise ratio (CT number of iodine solution divided by the background noise level) in small, medium, and large phantoms at different tube potentials.*

McCollough M, et al., RCNA, 2010
Over-ranging in CT scans

• Over-ranging is specific to reconstruction-algorithm
• Generally increases with collimation and pitch
• Over-ranging may lead to substantial but unnoticed exposure to radiosensitive organs

Adaptive Dose Shield

- Conventional pre-patient collimator results in over-scanning
- Adaptive dose shield minimizes radiation to target region and reduces overall dose

Deak, P. D. et al. Radiology 2009;252:140-147

Conventional and Adaptive Collimation

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Dose Reduction during Cardiac CT Imaging

Retrospective ECG Gating

Temporal Resolution
Radiation dose higher than prospective triggering

Continuous recording of spiral scan and ECG

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Prospective ECG Triggering

Temporal resolution
Radiation dose minimized
Limited data set

Conventional Axial “Partial Scan” (Step and Shoot)

Coronary CT Angiography:
Prospective Triggered vs Helical Retrospective gated

Effective dose for CTA portion:
4-6 mSv

Effective dose for CTA portion:
12-15 mSv

Retrospective ECG gating versus Prospective ECG gating


320 MDCT: Cardiac CTA Protocol
Single Heart Beat Protocol (for HR ≤ 65 bpm)

Single Heart Beat Protocol (for HR ≤ 65 bpm)

2-Heart Beat Protocol (for HR ≥ 65 bpm)

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Cardiac CT Imaging with DSCT

Weustink, A. C. et al. Radiology 2009;252:53-60

Beam shaping filters specific to cardiac CT

• Body and targeted field-of-view (cardiac) beam shaping filters

• Radiation dose outside the cardiac region can be lowered

Radiology 2007;243:775-784
Iterative Reconstruction

• Conventionally filtered back-projection has been the choice of CT image reconstruction
• Iterative reconstruction method makes several passes over the raw data (obtained at low dose techniques) to produce more accurate model of image and reduce amount of noise
• Can result in 40 to 80% reduction in radiation dose
• Trade-off: need for more processing power and additional time for the process
Iterative Reconstruction - Noise Reduction

Standard reconstruction  2 Iterations  2 Iterations

Courtesy: Dr. Mark Baker, Cleveland Clinic Foundation, Cleveland, OH

Comparison Full Dose / Dose Reduction 50% + iDose

120kV, 120/60 mAs
Apart from the cysts, the first CT shows thrombus in portal vein. On the follow up study, (6 weeks later) the thrombus has disappeared.

Follow up with 50% Dose Reduction

50% Dose (60 mAs) - FBP

50% Dose Reduction

50% Dose (60 mAs) - iDose

50% Dose Reduction

iDose

Full Dose (120 mAs) - FBP

50% Dose Reduction

50% Dose (60 mAs) + iDose

50% Dose Reduction

Philips

Courtesy Dr Dobritz, TU Munich, Germany

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Dual Energy CT (DECT) approaches

- Dual x-ray tube – each tube set at different kVp (Siemens Dual-Source CT)
- Switching kVp on fly to obtain dual energy CT data (GE)
- CT detector in sandwich form – yielding dual signal for each exposure
- Photon counting detector with energy resolving capability

Graser A et al. Radiology 2009;252:433-440

Triple Phase CT Protocols: Virtual vs True Non-enhanced Images

- Typical triple phase CT protocols
  - True non-enhanced + arterial + delayed phase
- Virtual non-enhanced images with DECT equivalent in image quality with true non-enhanced images
- Reduces dose by nearly 35%

Graser A et al. Radiology 2009;252:433-440
CT Dose – Positive Developments

- Increased awareness
  - Such as *Image Gently*® and *Image Wisely*® campaign
- American College of Radiology
  - Appropriateness Criteria
  - CT Accreditation program
- Education and Radiation awareness

ACR® Appropriateness Criteria*

- Evidence based guidelines to assist referring physicians and other providers in making most appropriate imaging or treatment decision for a special clinical condition
- Guidelines are developed by expert panels in diagnostic imaging, interventional radiology and radiation oncology
- As of 2010, AC is available for 169 topics

* [http://www.acr.org/secondarymainmenucategories/quality_safety/app_criteria.aspx](http://www.acr.org/secondarymainmenucategories/quality_safety/app_criteria.aspx)
• Increase awareness for need to decrease radiation dose to children during CT scans
• Down-size adult CT protocols to kids size
• Consider eliminating multi-phase scans

Image Wisely®

• Increase awareness for need to decrease radiation dose even in adult protocols
CT Dose Check*

- “Radiation dose check feature will provide an alert to CT machine operators when recommendation radiation levels as determined by users are exceeded”
- Feature expected to be available for new CT scanner soon
- CTDI_{vol} and DLP values can be set for each scan series so that when values exceeds set levels, program will alert operator and if he/she still wishes to continue with the changes then he/she needs to document the reasons
- Program will have capability to track changes that can be audited later

* NEMA XR 25-2010

Impact after implementing radiation reduction techniques

Distribution of Patients by Estimated Radiation Dose

Percentage of Patients Achieving Target Dose of Less Than 15 mSv by Bimonthly Intervals

Conclusions

• Radiation dose from CT is of concern and has been in the limelight recently
• Optimization of CT protocols are key
• New methods – both technological and practice methods are leading the efforts to reduce CT dose
• Dose reporting is becoming front and center
• Understanding radiation issues and justifying appropriateness of medical x-ray imaging is critical
Benefits of diagnostic radiation outweigh the dangers.

But experts recommend having a CT scan or X-ray only "if there's a good medical reason for it."