The State of the Art in CT
or
I can diagnose that case in 1 mSv!

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Where have we come (read “outline”)

- CT evolution from single to multi, slow to fast
- Hardware dose reduction
- Software dose reduction
- Conclusions

Notes
- I will call out vendor unique technologies, otherwise they are common. I received slides from all vendors.
- Focus is on dose reduction. There are many other advanced technologies that can’t be covered in 20 minutes!
CT Evolution

Multi Slice
4-Row Scanner

• Quantum leap over single slice
• Enabled true volume coverage
• Limitations
  – Tradeoff between coverage and slice thickness (resolution)
  – Not enough coverage for cardiac scanning
  – Dose penalty for thin slices
CT Evolution

4 Detector Row 16 Detector Row
3 mm. Polyp

1 mm. Slices
Routine Body CT Doses over 2 Decades

All solid state detectors

European Commission 2000 Reference Value

American College of Radiology 2007 Reference Value

- 10 mm section width
- 7 - 10 mm
- 1 - 5 mm

1980s Picker 1200 (3.3 mm Al)
1980s Picker 1200 (5.2 mm Al)
1987 Imatron EBCT (10 mm Al)
1988 GE 9800 (7.3 mm Al)
1994 GE HiSpeed (7.1 mm Al)
2002 GE LightSpeed 16 (8.3 mm Al)
2004 Siemens Sens. 64 (9.5 mm Al)
Dose Reduction

• Not just about the scanner
• Many players
  – Radiologist, technologist, medical physicist
  – Applications specialist, development engineer
  – Academic researcher, industry researcher
• Ultimate goal
  – Right scan on the right patient with the right dose
Top-of-the-Line Scanners

**GE Discovery CT750 HD**
- Fast kV switching
- HD mode
- Gemstone Detector
- ASiR

**Philips Brilliance iCT**
- 256 slices
- iDose$^4$
- 8 cm volume
- 0.27s rotation

**Siemens Flash**
- 2 x 128 slice
- High pitch helical
- IRIS
- 75 ms temp res

**Toshiba Aquilion ONE**
- 320 detector rows
- 16 cm volume
- AIDR
- Dynamic volumes

**Why it’s cool**
- Fast kV switching
- HD mode
- Gemstone Detector
- ASiR
- 256 slices
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Imaging Chain Hardware

Slide Courtesy of PHILIPS
- Other Considerations
  - Focal spot size
  - “flying” focal spots
Additional Beam Filtration

Quality of Dose Needed

Increase beam hardness and reduce soft radiation when possible

- 120 kVp
  - 30% dose reduction
- 80 kVp
  - 46% dose reduction

* relative to half-filter (softer beam)

Slide Courtesy of PHILIPS
Beam Shaping Filters

Dose Only **Where** Needed: Wedge/Bowtie Filters
Collimation

Lower dose, same IQ for helical scans

- Enhanced Z-axis tracking for additional dose reduction
- Automatically opens and closes cams at the beginning and end of helical scans to reduce unused dose
- Applied for all body and neuro helical acquisitions
- Can reduce total exam dose up to 6% for typical chest protocol*

*Routine chest protocol = 200mm coverage, 40mm aperture, and 1.375 pitch
Blocking unnecessary radiation
Independent Collimators

Conventional technology without independent collimators

New technology with adaptive independent collimators
Detectors and DAS

• Ceramic or garnet detectors
  – Fast decay
  – Short afterglow
  – Good stopping power
  – High light output

• Data acquisition system
  – High frequency readout (1 – 3 kHz)
  – Low electronic noise
2D Antiscatter Collimator

- Improves scatter to primary ratio (SPR): 3x reduction in scatter
- With a higher SNR, radiation dose may then be reduced
  - Up to **10%** for 12" phantoms
  - Up to **16%** for 16" phantoms
- Reduces scatter artifact and nonuniformity
- Increases low contrast for larger patients
- Spherical geometry for true cone-beam focus


Slide Courtesy of PHILIPS
Software Dose Reduction

• Automatic exposure control
  – XY and Z
  – ECG

• Prospective cardiac
  – Helical
  – Axial
  – Volume

• Right patient, right protocol, right dose
  – Pediatric protocols
  – Dose Check

• Advanced Reconstruction
Automatic Exposure Control

- XYZ mA modulation
- Scan projection radiograph based
- Optimized dose for image quality
  - Current selection
  - Modulation
ECG Modulation

- Low dose cardiac CTA acquired in helical mode
- Exposure is pulsed on/off for the same % R-R for each heart beat.
Axial cardiac

~80% Less Dose & Improved IQ

Prospective ECG gating axial scanning

Real-time heart rate monitoring and gating

Not a single phase; it is a phase range

Dose and exposure time are heart rate independent

Real-time adaptive scanning avoids unanticipated premature beat arrhythmias, improving overall scan reliability

Improves image quality during Axial cardiac scanning

Slide Courtesy of GE
2nd generation Dual Source CT
Image the heart in one beat at low dose

Conventional ECG-Gated Spiral
- Low pitch, slow scan speed
- Scan time 5 – 10 s heart, 10 – 20 s chest
- Redundant data → High dose

ECG-Triggered Flash Spiral
- High pitch, high scan speed
- Scan time 0.25 – 0.27 s heart, 0.6 – 0.7 s chest
- No redundant data → Low dose!
Dynamic Volume CT – Temporal Uniformity

Up to 16 cm coverage in one rotation
Targeted organ dose reduction
Dose reduction with X-CARE

Conventional Technology

- Full radiation of breast
- Breast is always included in any diagnostic thoracic scan, but almost never organ of interest

with X-CARE

- Up to 30 - 40% dose reduction
- No compromise in image quality
- For dose sensitive organs: e.g. breast and eye lens
Variable Helical Pitch vHp

- Changing table speeds within the same exam saves time, dose and cost
- Combining ECG and non ECG gated scans into one makes excellent use of contrast media with up to 40% dose reduction
Dedicated Protocol Selection
## Notification vs Alert

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<thead>
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<th></th>
<th>Notification</th>
<th>Alert</th>
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</thead>
<tbody>
<tr>
<td><strong>Values Checked</strong></td>
<td>CTDI\textsubscript{vol} and/or DLP</td>
<td>Cumulative CTDI\textsubscript{vol} per PT location and/or Cumulative DLP</td>
</tr>
<tr>
<td><strong>Context</strong></td>
<td>Current scan</td>
<td>Current patient</td>
</tr>
<tr>
<td><strong>Required before proceeding</strong></td>
<td>Confirmation, Comments (optional)</td>
<td>Confirmation, Operator’s name, Password (if configured), Comments (optional)</td>
</tr>
<tr>
<td><strong>Audit trail recorded</strong></td>
<td>Date/Time, Unique Study ID, Values exceeded, Corresponding dose index value, Comments</td>
<td>Date/Time, Operator’s name, Unique Study ID, Values exceeded, Corresponding dose index value, Comments</td>
</tr>
</tbody>
</table>
Advanced Reconstruction

- AIDR
- ASiR
- iDose$^4$
- IRIS
AIDR Algorithm

- Iterative Noise Reduction
- Reduces image noise by up to 50%
- Reduces dose by up to 75%

Slide Courtesy of TOSHIBA
Full dose without IRIS

60% less dose with IRIS

70% less dose with iDose

FPB at full dose
Dose Reduction- a multifaceted challenge

• Optimize the protocols
  – Size based-
    » Peds vs Adults
    » Obese vs thin
  – Task based
    » Limit to a single phase whenever possible
    » Tailor dose to the clinical question
Liver Volume

DLP = 1.5; Effective Dose = .097 mSv

About 5 chest x rays; less than 1 abd series!

Slide Courtesy of Don Frush, Duke
Dose Reduction - a multifaceted challenge

- Review the protocols
  - Clinician, technologist, physicist
  - Periodic reviews for consistency, dose

- Lock down the protocols
  - Once they have been reviewed and blessed
  - Password protection on scanners

- Dose reporting
  - IHE REM profile
  - Dose reviews
Dose Reduction - a multifaceted challenge

- Training of operators
  - Scanners are increasingly complex
  - Make sure all dose reduction features are understood and used

- Scanner Hardware

- Scanner Software

- Right exam on the

- Right patient with the

- Right dose
The Good News

- Cardiac (2009) = 15 mSv
- Cardiac (2011) = < 1 to 3 mSv