The new CT technology: what are the benefits?

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The new CT technology

- GE LightSpeed
- Siemens Sensation
- Toshiba Aquilion
- Philips Mx8000
What is the “new technology”? 

1. Hardware developments

- **Multi-slice acquisition**
  - 4-slice since 1999 (GE, Siemens, Toshiba, Philips)
  - 8-slice since 2001 (GE)
  - 16-slice since 2002 (GE, Siemens, Toshiba, Philips)

- **Half-second rotation**
  - 0.5 sec now standard on top models (all makes)
  - 0.42 sec cardiac option (Siemens, Philips)
What is the “new technology”? 

2. Software developments

• Image reconstruction and display
• Applications packages
• Exposure control

3. Cost

• Multi-slice in 2002 v. top range single-slice in 1998
  – Manufacturers A and B: “about the same”
  – Manufacturer C: “about £160k more”
How does the patient benefit?

• Are the images of greater diagnostic value?
  – better image quality?
  – improved imaging capabilities?

• Is patient comfort/compliance/safety improved?
  – formerly difficult procedures now more comfortable?
  – reduced risk of complications?
  – new CT techniques available that spare patient from more invasive diagnostic procedures?

• Are radiation doses any lower?
  – any different from single-slice scanning?
  – any dose reduction features?
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Axial image quality

- Most design features are same for single and multi-slice.
- Transverse axial scan image quality similar for multi and single slice scanners, *for a given slice thickness.*
Multi-slice scanning

- multiple banks of detectors
- single irradiation width
- 4 data sets
  - 4 axial images
  - 4 helical sets of data

\[
\text{or 8 or 16}
\]
Advantages over single slice

Either same acquisition in shorter time

or thinner slices for better z-axis resolution

or scan larger volumes in the same time
Shorter time $\rightarrow$ fewer motion artefacts

- e.g. aortic dissecton:
  - 500mm in 16 sec
  - 4 x 2.5mm slices
  - pitch 1.625

Courtesy: Dr. Baum, University of Erlangen
Thinner slices → better z-axis resolution

- Near-isotropic imaging achieved using 0.5 mm slices
- Finer detail perceptible in multi-planar reformats
Thinner slices → better 3D images

- Large numbers of narrow slices provide high quality volume rendering
- Stair-step artefacts virtually eliminated, edges well-defined

Courtesy: GE Medical Systems
Longer volumes → more useful scans

How many 1 mm slices in 30 sec scan time?

- 30 1 sec rotation, single-slice
- 60 0.5 sec rotation, single-slice
- 240 0.5 sec rotation, four-slice

Courtesy: Siemens
What evidence is there of improvements?

• Abdominal imaging
  – improved tumour detection rate in liver
  – improved staging of pancreatic cancer
  – improved polyp detection in CT colonography
  – planning renal surgery

• Chest imaging
  – “the new gold standard for detecting pulmonary emboli”
  – pulmonary and systemic circulation
  – bronchial tree disorders
  – focal and diffuse lung diseases
  – quantification of thoracic lesions
Advantages for CT angiography

• The more slices that can be acquired per rotation
  – the longer the volume that can be scanned
  – the higher the resolution possible

• e.g entire lower limbs scanned in single helical run
  – with 4-slice system, have to use ~3 mm slice
  – with 16-slice system, can perform high-resolution angiography using 1 mm slice
Advantages for CT angiography

• e.g. kidney donor angiogram: choosing which kidney to harvest
  – 16 x 0.625 mm
  – pitch 0.938
  – volume rendered reconstruction

• choose kidney with only one renal artery, or one with longest artery

Courtesy: GE Medical Systems
Vessel analysis

- Software package:
  - straightens out vessel of interest
  - plots diameter of vessel lumen

Lumen
Ex: 6005
Se: 2 tc
Carotis interne
Angle: -90° Rfmt
LP: 115.8
2/0
DFOV 23.3 cm

Width: 4.0 cm

Section Area
24.9 mm²

Lumen view is NOT intended for diagnosis

Courtesy: GE Medical Systems
Artefacts in multi-slice scanning

- Motion artefacts reduced by faster scanning
- Stair-step artefacts in 3D reconstructions reduced by using thinner slices
- Partial volume artefacts reduced by using thinner slices
- Streaking artefacts due to photon starvation more likely with thin slices. Can these be reduced?
Methods of image reconstruction

2-point interpolation as used on single-slice

Filter interpolation as used on multi-slice

Image plane

Filter width
Multi-dimensional adaptive filtering (MAF)

- For data points below selected attenuation threshold:
  - extra wide z-filter is applied for part of each rotation
  - for each projection, neighbouring detector channels are averaged
  - for each detector, signal is averaged between successive sampling angles
- To minimise blurring, <5% data points modified
Effects of 3D filtration

Standard  With MAF

Courtesy: Prof. Kalender, University of Erlangen
Noise reduction using 3D filtration

- "Noise in the pelvis typically reduced by 50% to 70%"
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• Are there any artefacts specific to multi-slice scanning? Can they be overcome?
The cone beam problem

- Data collected for each detector acquisition corresponds to volume between two cones, not a flat plane

- Worse for data collected by outer detectors than by inner detectors
Cone beam artefact

Image from centre detector row

Image from outer detector row
Cone beam effect

- Off-axis objects are “seen” by different detector rows for different tube angulations.
- Mis-registration of data leads to artefacts in the image.
- Effect gets worse the larger the cone angle and the thinner the slice.
- \[ \therefore \] 16-slice scanners affected more than 4-slice.
Solving the cone beam problem

- For 8- and 16-slice scanners, manufacturers employ various forms of cone beam reconstruction instead of standard z-filter interpolation.
- e.g. ASSR:

Stage 1: Stage 2:

Axial plane

Tilt plane

z
<table>
<thead>
<tr>
<th></th>
<th>Single-slice</th>
<th>8-slice</th>
<th>8-slice</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resolution</td>
<td>1 x 1.5 mm</td>
<td>8 x 1.5 mm</td>
<td>8 x 1.5 mm</td>
</tr>
</tbody>
</table>

Effects of using cone beam algorithm

Courtesy: Prof. Kalender, University of Erlangen
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Improved patient comfort and compliance

- Paediatric: faster imaging requires less sedation
- Trauma: larger single scan volumes
- High quality MPRs can mean more comfortable patient positioning
  - e.g. sinus images reconstructed from axial scans:

Courtesy: Siemens
Reduced risk of complications

- Less contrast required with faster scanning
- Advantages for CT perfusion studies
  - e.g. stroke assessment
CT Perfusion

- xenon gas previously used
  - patients not very tolerant
  - scans taken over 5 - 10 minutes at 1 minute intervals

- faster scanning means ionic contrast can now be used
  - continuous scanning of the brain during contrast injection
  - scan time < 1 minute
Sparing invasive procedures

- e.g. colonography:

Courtesy: GE Medical Systems
Cardiac CT with earlier technology

- Cardiac movement caused blurring and severe motion artefacts

Courtesy: Prof. Kalender, University of Erlangen
Cardiac CT now

Compared with MRI and EBCT:

- Temporal resolution now almost comparable because of:
  - sub-second rotation times
  - ECG gating
  - multi-slice technology
- Better spatial resolution
- Advantages in cost, availability and patient comfort

Heart rate 90 beats/min

Courtesy: Kalender, University of Erlangen
Prospective ECG gating

- Start of each axial scan triggered by ECG signal to coincide with heart phase with least motion
- Can produce partial rotation scan in ~0.25 sec
Retrospective ECG gating
Retrospective ECG gating

- Image reconstructed using only portions of helical data collected during diastole
- Need pitch \( \approx 0.3 \) :: high dose
Cardiac calcification scoring

- Analysis of calcified coronary plaque used in diagnosis of coronary artery disease
CT coronary angiography

- Stenosis detectable in vessels down to 1.5 mm diameter

Courtesy: Prof. Kalender, University of Erlangen
Phase-selective reconstruction

- Determine heart motion function instead of ECG
- Use as basis for phase-selective reconstruction

ECG-gated reconstruction  Motion-correlated reconstruction

Courtesy: Prof. Kalender, University of Erlangen
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Multi-slice v. single-slice doses

- For wide slices, doses are similar on single- and multi-slice scanners in axial mode

- Effect of helical pitch on noise is different on multi-slice than on single-slice
  - To keep noise the same, mA increases automatically with increasing pitch on multi-slice
  - mA kept the same with pitch on single-slice because noise does not vary
How might doses be higher with multi-slice?

• More CT scans likely to be performed because of the greater range of scanning capabilities
  ∴ increase in overall dose burden

• Use of CT for screening
  – e.g. lung cancer and colon cancer screening in high-risk groups

• Greater use of narrow slices
  – need higher mA to keep noise acceptable (partly offset by improved contrast due to less partial volume effect)
  – doses higher for narrow collimations because of beam penumbra
Thin slices: contribution of penumbra

- Single-slice detector: penumbra contributes to image, \( \therefore \) no wasted dose
- 4-slice acquisition: penumbra contributes significant unused radiation dose
- 16-slice acquisition: unused penumbra constitutes much smaller proportion of total dose
# Geometric efficiencies

<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>Scanner</th>
<th>Collimation</th>
<th>Geometric efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>GE</td>
<td>LightSpeed Plus</td>
<td>4 x 1.25</td>
<td>63%</td>
</tr>
<tr>
<td></td>
<td>LightSpeed Ultra</td>
<td>8 x 1.25</td>
<td>76%</td>
</tr>
<tr>
<td>Philips</td>
<td>Mx8000 Quad</td>
<td>2 x 0.5</td>
<td>48%</td>
</tr>
<tr>
<td></td>
<td>Mx8000 Quad</td>
<td>4 x 1</td>
<td>68%</td>
</tr>
<tr>
<td></td>
<td>Mx8000 Infinite</td>
<td>16 x 0.75</td>
<td>93%</td>
</tr>
</tbody>
</table>
How might doses be lower?

- “Two-for-one” scanning
- e.g. high-res. lung + mediastinum
  - single scan using 4x1 mm collimation:

  1.25 mm reconstructions, 0.5 mm intervals
  5 mm reconstructions, 2.5 mm intervals

Courtesy: Siemens
Dose reduction features

• Tube current modulation
  – varies mA to match variations in attenuation

• Paediatric protocols
  – chose mA and kV appropriate to child’s size
Matching tube current to attenuation

• Problem: different patient diameters and attenuation
  – from patient to patient
  – along patient length
  – in AP and lateral directions

• Solution: automatic control of tube current (mA)
Tube current modulation

- Method 1: use one or more SPRs to assess attenuation along patient length
  - vary overall mA according to patient size
  - vary mA slice by slice during scan (e.g. GE’s Auto mA)

- Method 2: use feedback mechanism
  - adjust mA based on signal to detectors during previous rotation (e.g. Siemens CARE Dose, Philips DoseRight)

- Advantages
  - lower dose (e.g. mean mAs reduction of 28% with CARE Dose)
  - image quality is constant, with fewer artefacts
  - tube heat capacity conserved
ECG-gated mA modulation

- ~50% dose reductions reported using this technique
- Further significant dose savings possible by using 80 kV rather than 120 kV without compromising image quality
Paediatric protocols

• GE’s colour coded system
  – assigns scan parameters according to child’s weight and height
  – ties in with hospital-wide Rainbow System which covers drug doses, needle sizes etc

• Philips and Siemens systems
  – protocols specific to weight and age
Conclusions

• New technology proving its worth:
  – in routine scanning
  – in more specialised fields

• CT scanning procedure may:
  – be more comfortable for the patient
  – carry fewer risks of complications
  – sometimes replace more invasive procedures

• CT doses:
  – likely to increase overall for the population
  – higher for some exams but could be lower for others
  – thin slice doses on 8- and 16- slice lower than on 4-slice
  – are being addressed by dose reduction features