Image Quality and Dose

- Image quality
  - Image noise
  - Spatial resolution
  - Contrast
  - Artefacts

- Radiation Dose
  - Organ dose
  - Effective dose

What we find is that they are all in a constant battle with each other – each can only win at the expense of another.

Scanner parameters affecting IQ and Dose

- Beam shaping filter
- mA
- Scan time
- kV
- Convolution kernel
- Detector size
- No. of samples
- Image width
- Beam width
- Pitch
Scanner parameters affecting IQ and Dose

- Beam shaping filter
- mA
- Scan time
- kV
- Convolution kernel
- Detector size
- No. of samples
- Image width
- Beam width
- Pitch

IQ and Dose in MSCT

- Spatial resolution (z-axis)
- Pitch
- Dose issues
- Reconstruction algorithm
- What image quality do we want?

Spatial Resolution – 3D

- Scan plane (limited by pixel size)
- Z-axis (image slice width)

High contrast spatial resolution

- How small can we go?

Z-axis spatial resolution

- Imaged slice width
  - Influences partial volume artefacts
  - Affects contrast and noise
- In MSCT
  - Flexibility of reconstructing different slice widths
- In helical generally (SS and MS)
  - Optimised by reconstructing overlapping slices
Z-axis spatial resolution

- Thinner slice minimises partial volume artefacts

Wider Narrower

- Thicker slice
- Thinner slice

Thinner slice - improved contrast

- Image width affects contrast and noise of object
- Optimised slice width: imaged slice ≈ object size

Thinner slice - higher noise

- Object ~ 5 mm

Z-axis resolution in single-slice

- Image width depended on beam width
  - And post patient collimation for thin slices

Courtesy: Matthew Benbow, RBH
**Z-axis resolution in multi-slice**

- Image width depends on detector acquisition width
  - eg 4 x 5mm, will not give a 2.5 mm slice! (Use 8 x 2.5)
- May be optimised in helical
  - with closer z-axis sampling
    (eg z-sharp in Siemens, or certain overlapping pitches)

**Optimising z-axis spatial resolution**

- Visualisation optimised by overlapping reconstructions
  (viewed by cine or 3-D)
  - object
  - transaxial images
  - MPR
  - Overlapping reconstructions recommended for optimum contrast and z-axis resolution
  - ½ to 2/3rd overlap recommended

**Effect of pitch**

- SSCT vs MSCT
  - Dose
  - Noise
  - Image slice thickness
- Artefacts

**Pitch – dose**

- Overlapping pitch – average dose increases
- Extended pitch – average dose lower
Pitch - single slice (increase pitch, mA const)

- Dose decreases
- Noise constant with pitch
  - Two point interpolation regardless of spacing
- Image width increases

Pitch – multislice (inc. pitch, mA const.)

- Dose decreases
- Same filter width
  - Image width remains the same
- Noise increases:
  - less projection data within filter width

Pitch – multislice (inc. pitch, inc. mA)

- Dose stays the same
- Same filter width
  - Image width remains the same
- Noise stays the same:
  - less projection data within filter width,
  - but more photons per projection

Pitch – artefacts

- Teflon (PTFE) rod in water
  - to simulate rib at an angle to scan plane
- Spiral Artefacts in MPRs

Pitch – artefacts

- Spiral Artefacts in MPRs of a Tilted Teflon Rod
  - image-width 3mm
  - acquired using 4 x 2.5mm (Siemens Volume Zoom)

- For a given image width:
  - small detector acquisition width at higher pitch is better than wide acquisition width at lower pitch

Images courtesy Kalendar
Dose issues in MSCT

- Beam width (overbeaming)
- Helical overscan (overranging)

Dose issues in MSCT - Beam width

- Penumbra typically 3 mm for all beam widths
  - lower proportion of total dose with wider beam widths
- Wider is generally better

Dose issues in MSCT - Overranging

- Except for short scan lengths and large pitches near sensitive organs
  - Use narrower beam widths, or axial scans

Effect of reconstruction filter

- Filter used in backprojection (convolution kernel)
  - Smooth, standard, detail, bone
  - AH30, AH40, AB50
  - FC41, FC43... etc, etc
- Used to optimise spatial resolution against noise

Effect of reconstruction filter

- higher spatial frequency ⇒ more noise

Tube current

- 200 to 100 mAs ⇒ noise x 1.4
Low contrast detectability – recon filter

Smooth Bone

Same mAs

Similar noise

Compromise depending on requirements

• High spatial detail
• Low contrast resolution

Image noise

• What is an appropriate level of image noise?

10 mGy 15 mGy 20 mGy

25 mGy 30 mGy 35 mGy

Doses given are CTDI measured at surface of Catphan

Systematic addition of image noise

• Systematic addition of noise to clinical images/raw data
  – Simulate mA
• Studies for a variety of clinical conditions and scanners

decreasing photons per projection →

Ideal image 1,000,000 100,000 10,000

Image quality required for diagnosis

Scan Simulator: Courtesy of Toshiba
Image quality required for diagnosis

Systematic addition of image noise

- Frush et al ‘Computer simulated radiation dose reduction for abdominal multidetector CT of Pediatric patients’ AJR:179, November 2002

original 120 mA
simulated 100 mA
simulated 80 mA

What noise level is needed?

Original (16 x 1 mm, 200 mAs, pitch 0.9375)
Plain (no contrast) Early Late

Scanned dose: 1
Noise SD: 8.0

Images courtesy Y. Muramatsu, NCC Tokyo

What noise level is needed?

Simulation
Plain Early Late

Dose Ratio: 0.83
SD: 8.5

Images courtesy Y. Muramatsu, NCC Tokyo
What noise level is needed?

Simulation

Plain Early Late

Dose Ratio: 0.50
SD: 10.0

Images courtesy Y. Muramatsu, NCC Tokyo

Dose Ratio: 0.33
SD: 11.5

Images courtesy Y. Muramatsu, NCC Tokyo

Dose Ratio: 0.25
SD: 13.5

Images courtesy Y. Muramatsu, NCC Tokyo

Dose Ratio: 0.17
SD: 16.5

Images courtesy Y. Muramatsu, NCC Tokyo

Dose Ratio: 0.13
SD: 19.5

Images courtesy Y. Muramatsu, NCC Tokyo

Dose Ratio: 0.08
SD: 25.0

Images courtesy Y. Muramatsu, NCC Tokyo
What noise level is needed?

Simulation

Plain  Early  Late

Dose Ratio: 0.04

SD: 42.0

Images courtesy Y. Muramatsu, NCC Tokyo

IQ and Dose in MSCT

- Spatial resolution (z-axis)
- Pitch
- MSCT dose issues
- Reconstruction algorithm
- What image quality do we want?

Image Quality and Dose Issues in MSCT

S. Edyvean

ImPACT