Image Quality and Dose Issues in MSCT

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ImPACT

Image Quality and Dose

- Image quality
  - Image noise
  - Spatial resolution
  - Contrast
  - Artefacts
- Radiation Dose
  - Organ dose
  - Effective dose

'Speckle and sharpness'

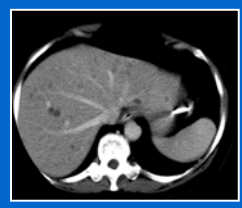

Image Quality and Dose

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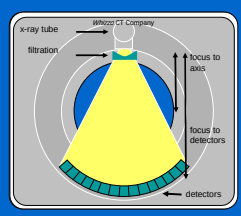
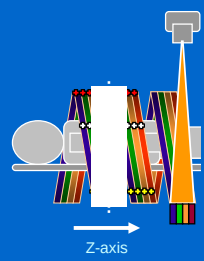
  - Image noise
  - Spatial resolution
  - Contrast
  - Artefacts
- Radiation Dose
  - Organ dose
  - Effective dose

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

Image Quality and Dose Issues in MSCT

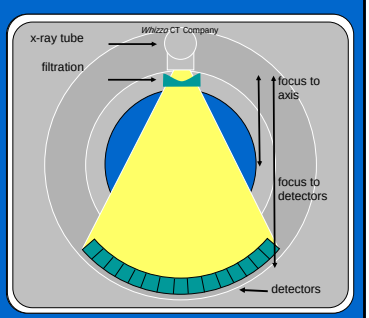
- Many issues are the same in ss and ms
  - General comments
  - Specific comments to msct
    - tend to relate to z-axis features





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



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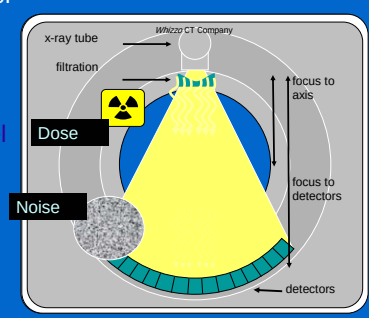

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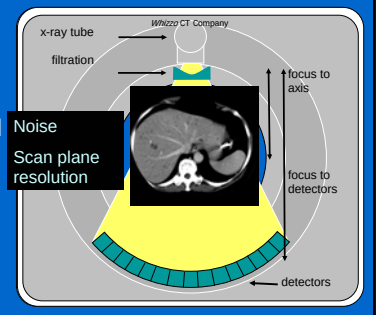

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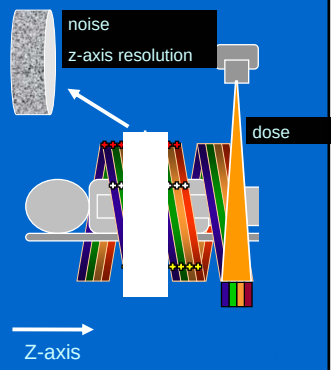
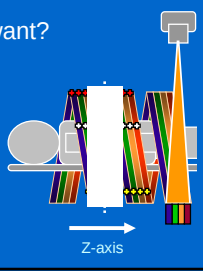


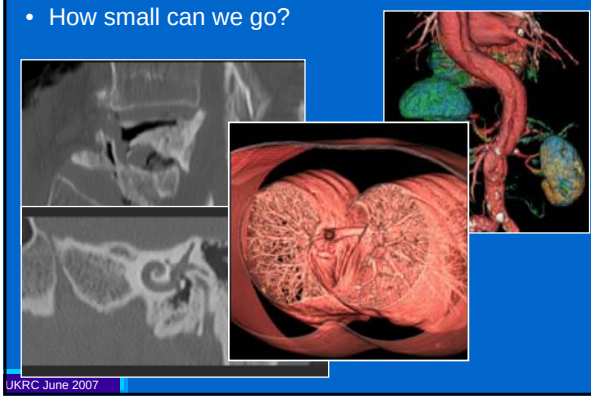
IQ and Dose in MSCT

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



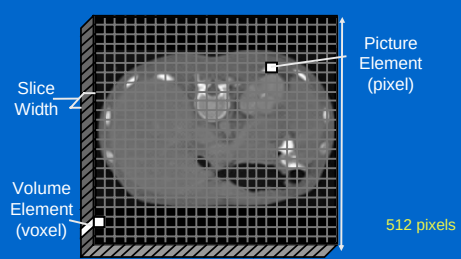
High contrast spatial resolution

- How small can we go?



Spatial Resolution – 3D

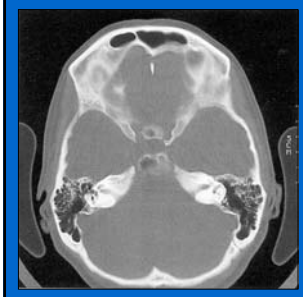
- Scan plane (limited by pixel size)
- Z-axis (image slice width)

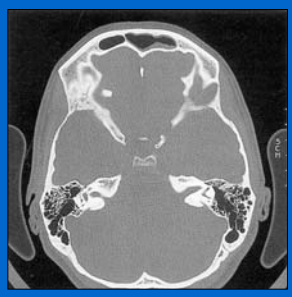


Z-axis spatial resolution

- 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



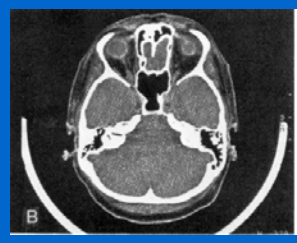


Wider

Narrower

Z-axis spatial resolution

- Thinner slice minimises partial volume artefacts

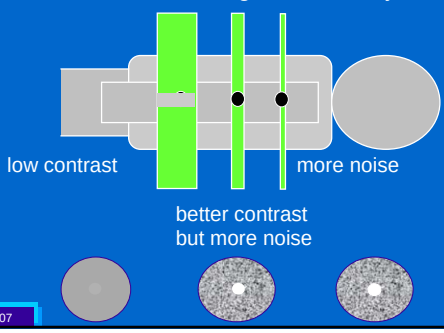


Thick slice

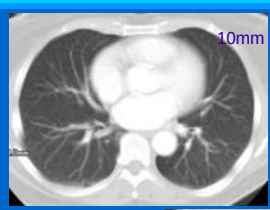
Thin slice

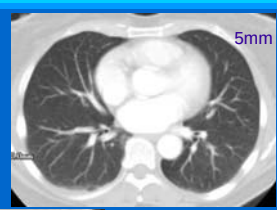
Z-axis spatial resolution

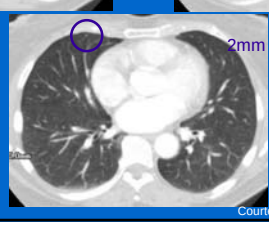
- Image width affects contrast and noise of object
- Optimised slice width: imaged slice ≈ object size



Thinner slice – improved contrast



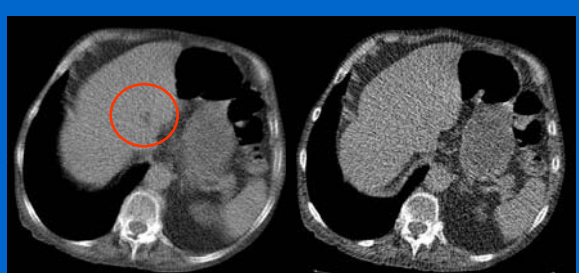




Courtesy: Matthew Benbow, RBH

Thinner slice - higher noise

- Object ~ 5 mm



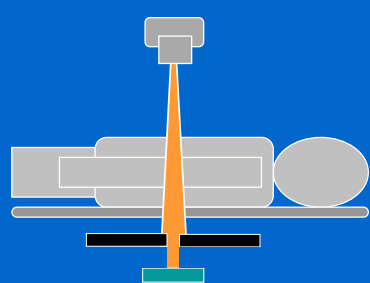
5mm

1mm

Courtesy: Matthew Benbow, RBH

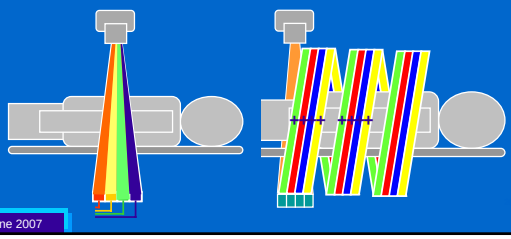
Z-axis resolution in single-slice

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



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)



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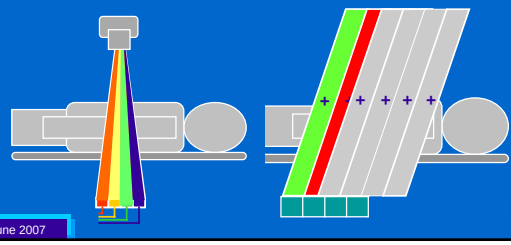
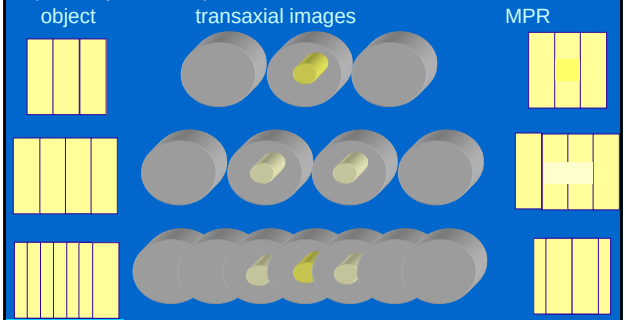


UKRC June 2007

Optimising z-axis spatial resolution

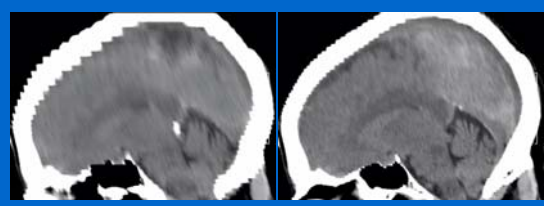
- Visualisation optimised by overlapping reconstructions
  (viewed by cine or 3-D)



UKRC June 2007

Optimising z-axis spatial resolution

- Overlapping reconstructions recommended for optimum contrast and z-axis resolution
- ½ to 2/3^{rds} overlap recommended



UKRC June 2007

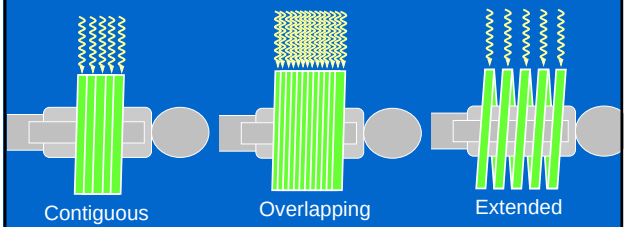
Effect of pitch

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

UKRC June 2007

Pitch – dose

- Overlapping pitch – average dose increases
- Extended pitch – average dose lower



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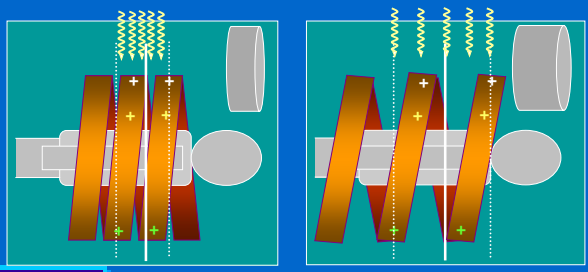
Pitch - single slice (increase pitch, mA const)

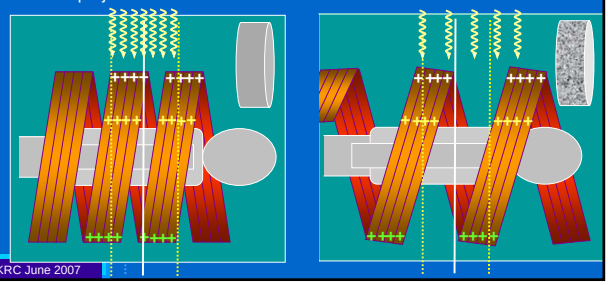
- Dose decreases
- Noise constant with pitch
  - Two point interpolation regardless of spacing
- Image width increases



2-point interpolation (360LI shown)

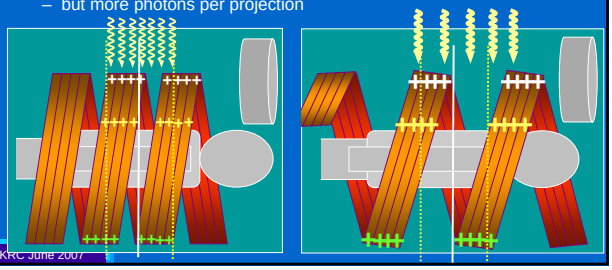
Pitch – multislice (inc. pitch, mA const.)

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



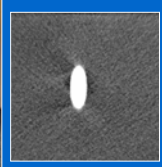
Pitch – multislice (inc. pitch, inc. mA)

- 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



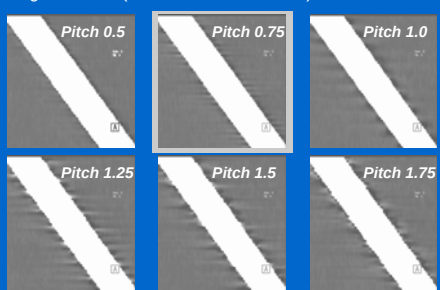
x-sectional image

MPR

Pitch – artefacts

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

gradual decrease of image quality



images courtesy Kalendar

Pitch – artefacts

- Spiral Artefacts in MPRs of a Tilted Teflon Rod

image-width 3mm

Volume Zoom 4 slice

Pitch 0.75, coll. 4 x 2.5mm

Volume Zoom 4 slice

Pitch 1.75, coll. 4 x 1mm

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

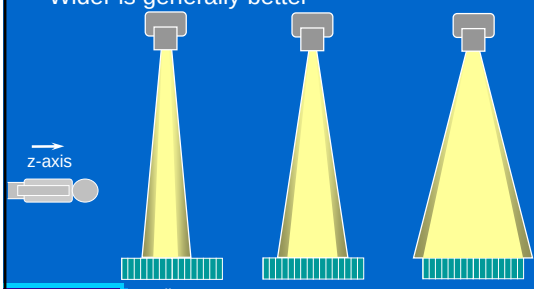
courtesy Kalendar

Dose issues in MSCT

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

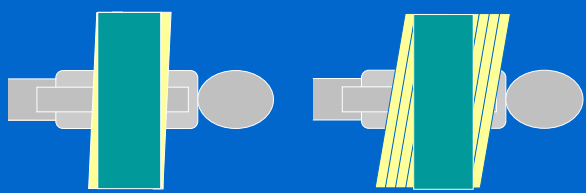
Dose issues in MSCT - Beam width

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



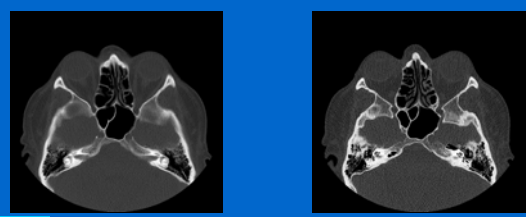
Dose issues in MSCT - Overranging

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



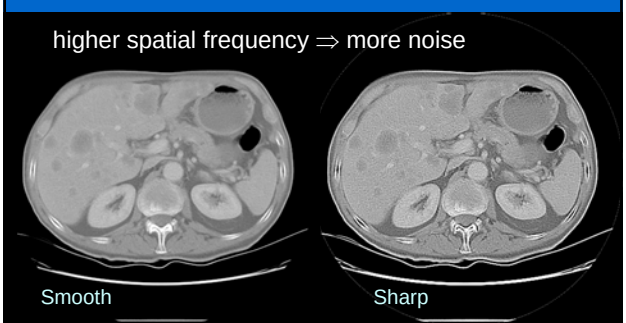
Effect of reconstruction filter

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



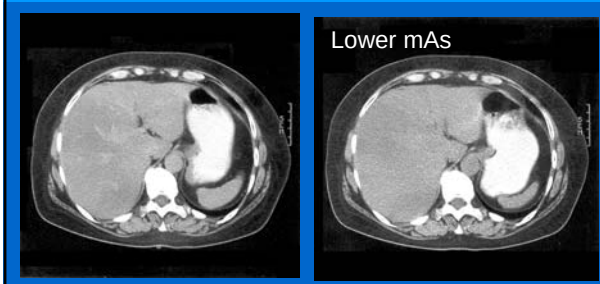
Effect of reconstruction filter

higher spatial frequency ⇒ more noise



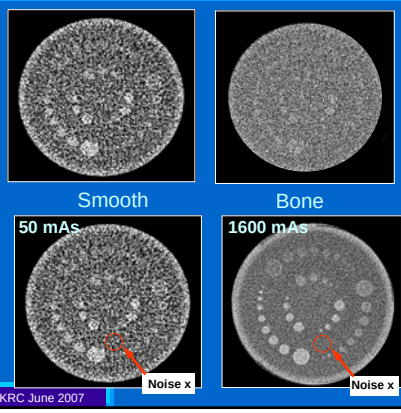
eg	Smooth	→	Standard	→	Sharp
noise =	~ 7 HU	→	17 HU	→	70 HU

Tube current



200 to 100 mAs ⇒ noise x 1.4

Low contrast detectability – recon filter



Compromise depending on requirements

- High spatial detail
- Low contrast resolution

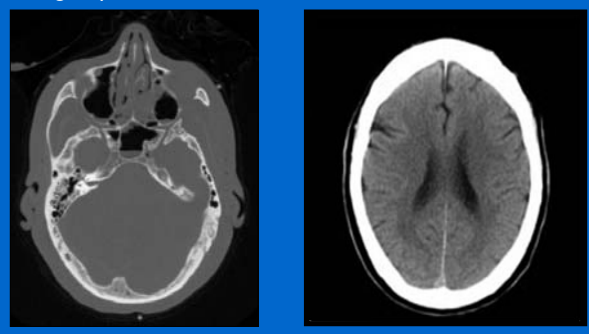
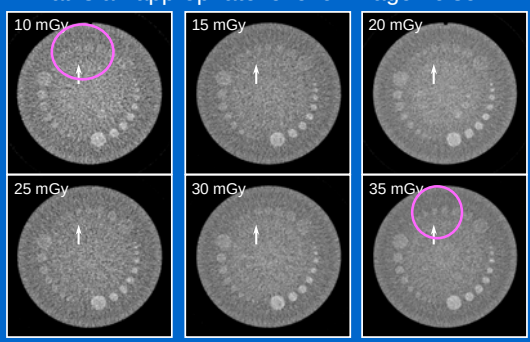


Image noise

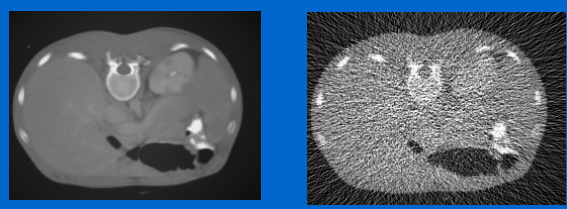
- What is an appropriate level of image noise ?



Doses given are CTDI measured at surface of Catphan

Image noise

- What is an appropriate level of image noise ?
  - too low – high dose
  - too high – no diagnosis / missed diagnosis
- How do we find the optimum level?



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 →

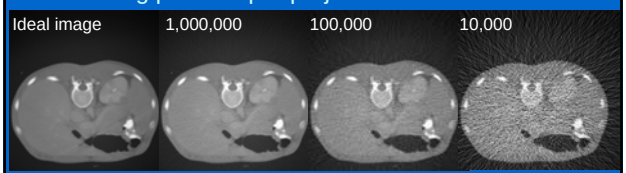
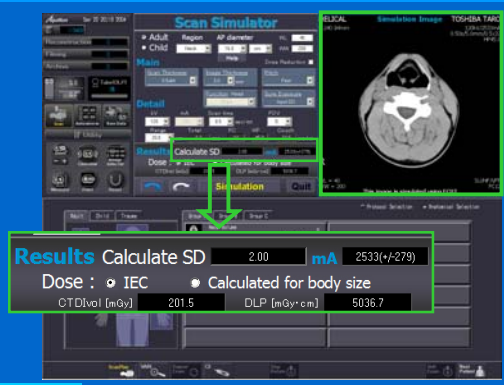
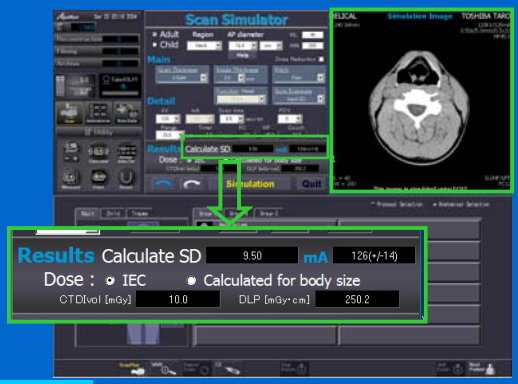


Image quality required for diagnosis



Scan Simulator: Courtesy of Toshiba

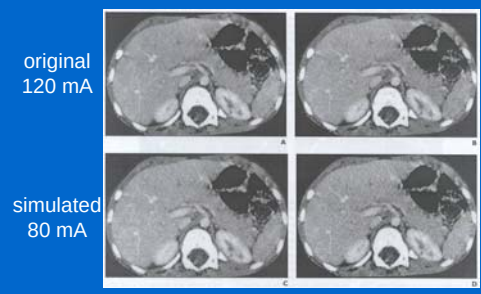
Image quality required for diagnosis



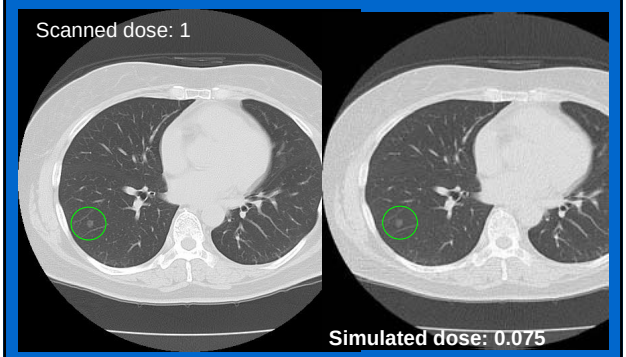
Scan Simulator: Courtesy of Toshiba

Systematic addition of image noise

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



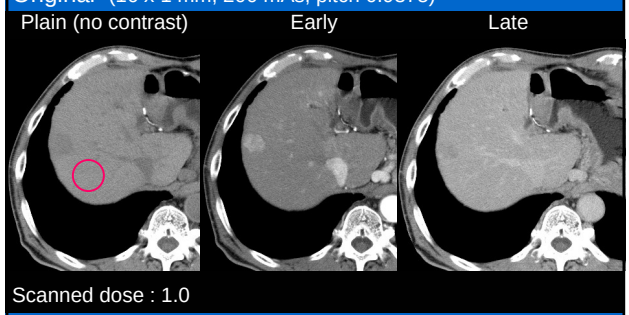
What noise level is needed?



Images courtesy Y. Muramatsu, NCC Tokyo

What noise level is needed?

Original (16 x 1 mm, 200 mAs, pitch 0.9375)

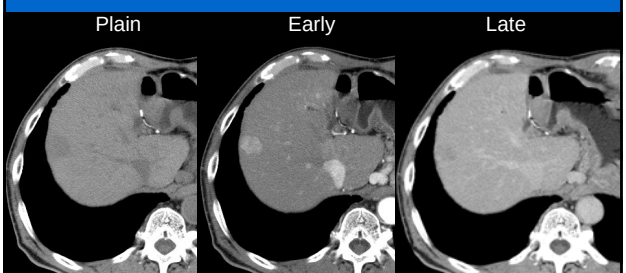


Noise SD: 8.0

Images courtesy Y. Muramatsu, NCC Tokyo

What noise level is needed?

Simulation



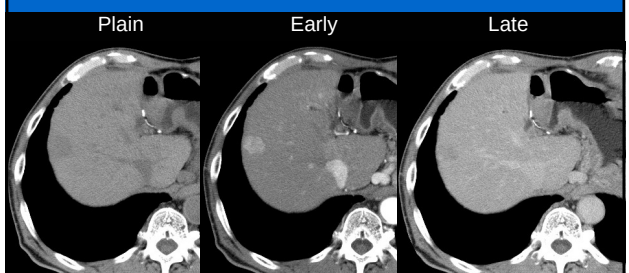
Dose Ratio: 0.83

SD: 8.5

Images courtesy Y. Muramatsu, NCC Tokyo

What noise level is needed?

Simulation



Dose Ratio: 0.67

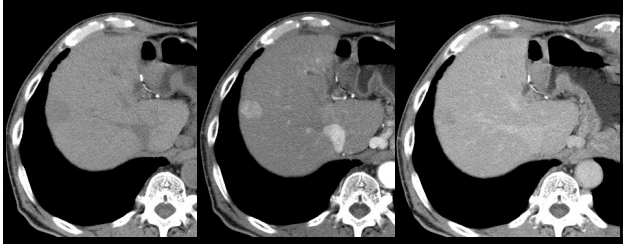
SD: 9.0

Images courtesy Y. Muramatsu, NCC Tokyo

What noise level is needed?

Simulation

Plain | Early | Late



Dose Ratio: 0.50

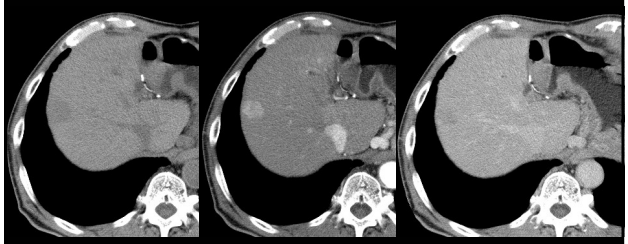
SD: 10.0

Images courtesy Y. Muramatsu, NCC Tokyo

What noise level is needed?

Simulation

Plain | Early | Late



Dose Ratio: 0.33

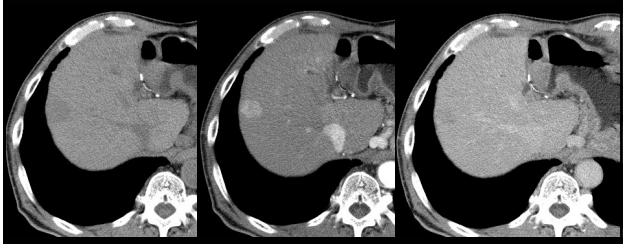
SD: 11.5

Images courtesy Y. Muramatsu, NCC Tokyo

What noise level is needed?

Simulation

Plain | Early | Late



Dose Ratio: 0.25

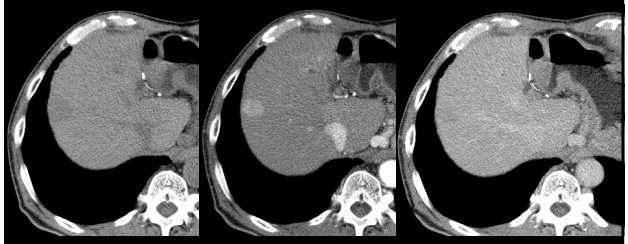
SD: 13.5

Images courtesy Y. Muramatsu, NCC Tokyo

What noise level is needed?

Simulation

Plain | Early | Late



Dose Ratio: 0.17

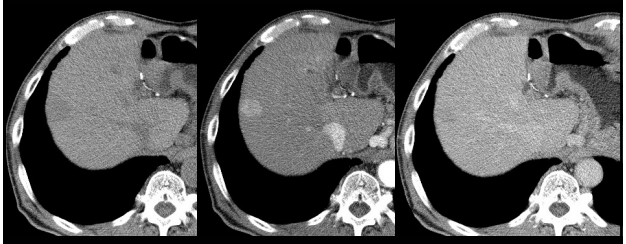
SD: 16.5

Images courtesy Y. Muramatsu, NCC Tokyo

What noise level is needed?

Simulation

Plain | Early | Late



Dose Ratio: 0.13

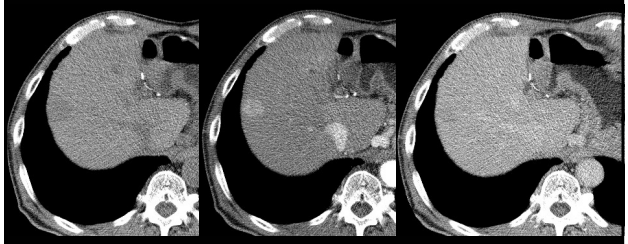
SD: 19.5

Images courtesy Y. Muramatsu, NCC Tokyo

What noise level is needed?

Simulation

Plain | Early | Late



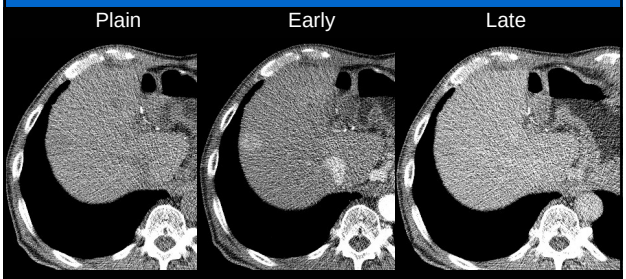
Dose Ratio: 0.08

SD: 25.0

Images courtesy Y. Muramatsu, NCC Tokyo

What noise level is needed?

Simulation



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