The effect of CT reconstruction kernel and post processing filter upon Hounsfield number constancy in radiotherapy treatment planning

Sarah Kirwin

Keith Langmack

Angela Nightingale

Nottingham City Hospital

Overview

- The role of CT in RT treatment planning
- What variation in HU is acceptable in RT treatment planning?
- The effect of reconstruction kernel on HU constancy
- The effect of post-processing filter on HU constancy
- Conclusions

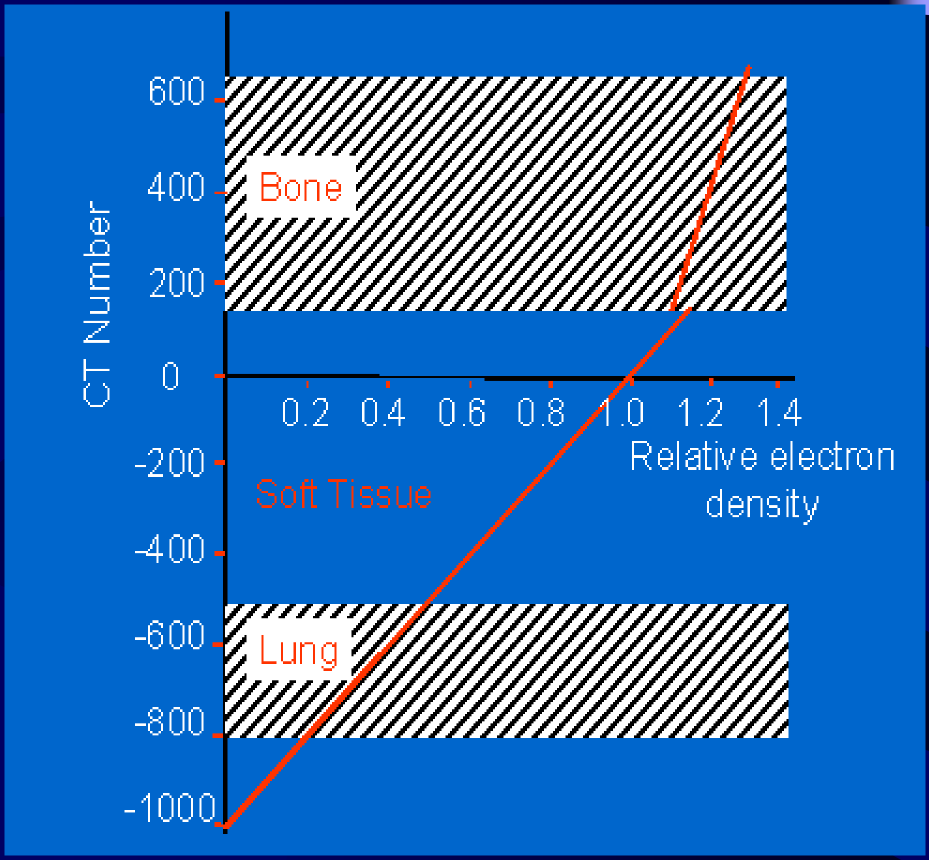
CT in RT treatment planning

- CT images provide accurate assessment of patient geometry
- HU data gives relative electron density information allowing tissue inhomogeneity to be accounted for
- Therefore HU constancy is important in RT treatment planning

HU and relative electron density

$$\mathrm{HU} = 1000\left(\frac{\mu - \mu_w}{\mu_w}\right)$$

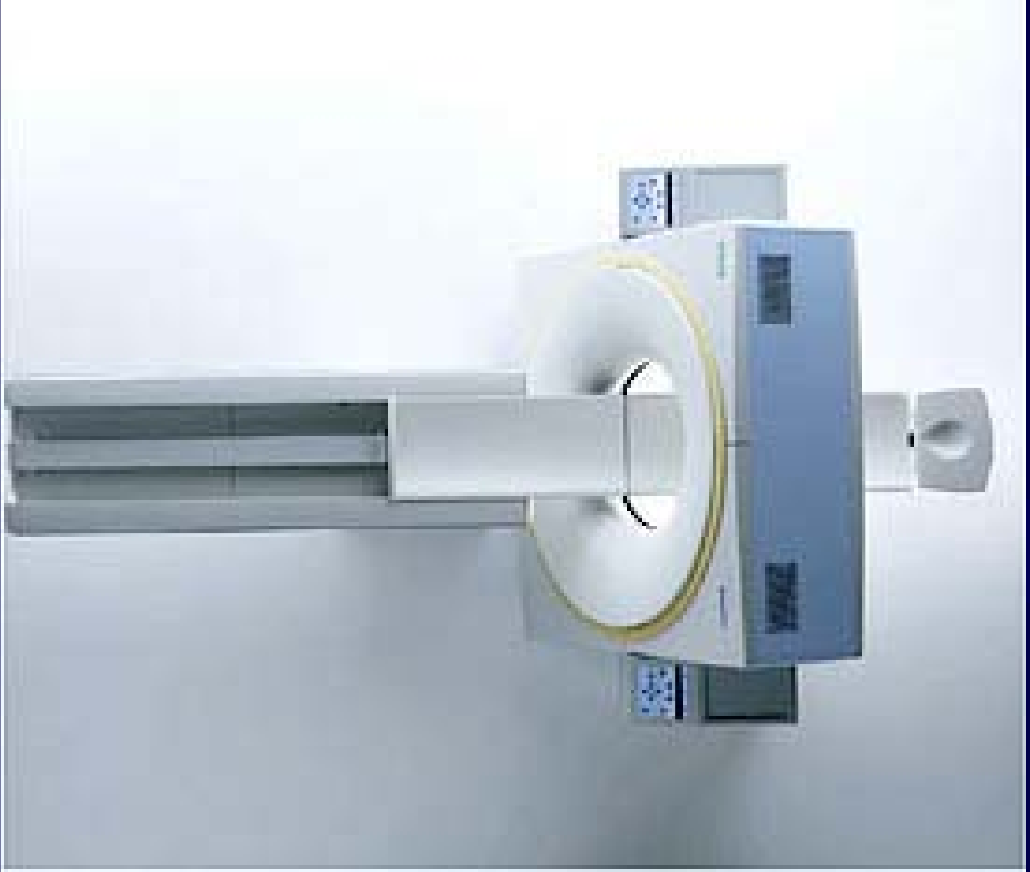
- Attenuation coefficient depends on electron density
- Relationship between relative electron density (ρ_e) and HU
- Probability of Compton interaction proportional to ρ_e



What variation in HU is acceptable?

- Consider photon beam energy of 6 MV, max tissue depth of water, lung and bone
- Change in ρ_e to produce a 2 % error in dose: ± 0.03 for water, ± 0.05 for lung, ± 0.08 for bone (Kilby et al 2002)
- Using relationship between ρ_e and HU (Thomas 1999, Knoos et al 1985) corresponding HU tolerances
  - 30 HU for water
  - 50 HU for lung
  - 160 HU for bone

NCH radiotherapy CT scanner



Siemens SOMATOM Emotion Duo

Reconstruction kernels

- Range of ‘head’ kernels: H10s – H80s
- Range of ‘body’ kernels: B10s – B90s
- U90s kernel
- Lower number smoother image
  - contrast detail better
  - noise level lower
  - edge definition poorer
- Higher number sharper image
  - spatial resolution better
  - noise level higher
  - edge definition better

QUASAR Body Phantom

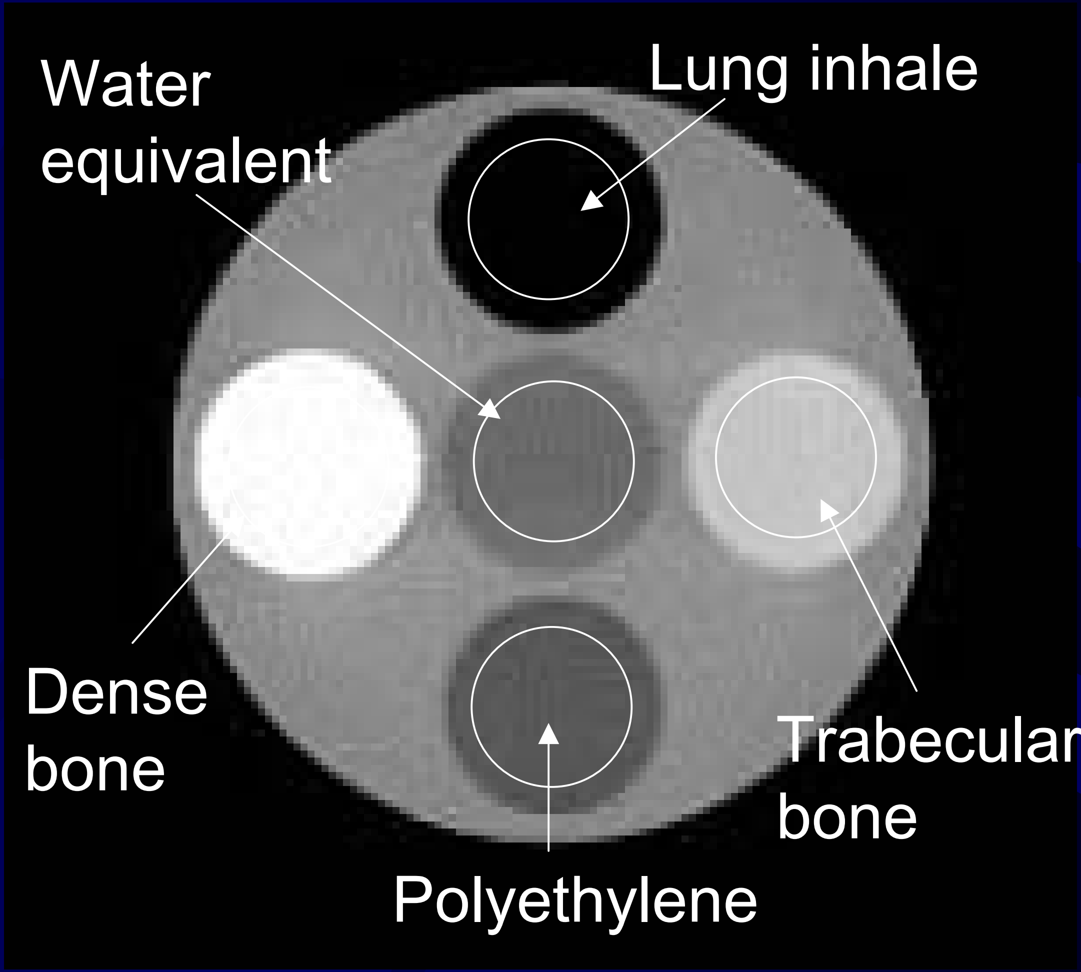
- Five electron density rods
  - Lung inhale (ρ_e = 0.190)
  - Polyethylene (ρ_e = 0.945)
  - Water equivalent (ρ_e = 1.002)
  - Trabecular bone (ρ_e = 1.117)
  - Dense bone (ρ_e = 1.512)
- Rod diameter 2.5 cm
- Rod length 2.5 cm

Effect of kernel choice on HU constancy - method

- ED rods in QUASAR phantom scanned axially (slice thickness 3 mm, 200 mAs)
- Three tube voltages used: 80, 110 & 130 kV
- Each of kernels used in turn to reconstruct images of the phantom
- CT slice through centre of rods located
- Circular ROIs drawn over ED rods in image
- Mean and SD of HU values in ROIs recorded

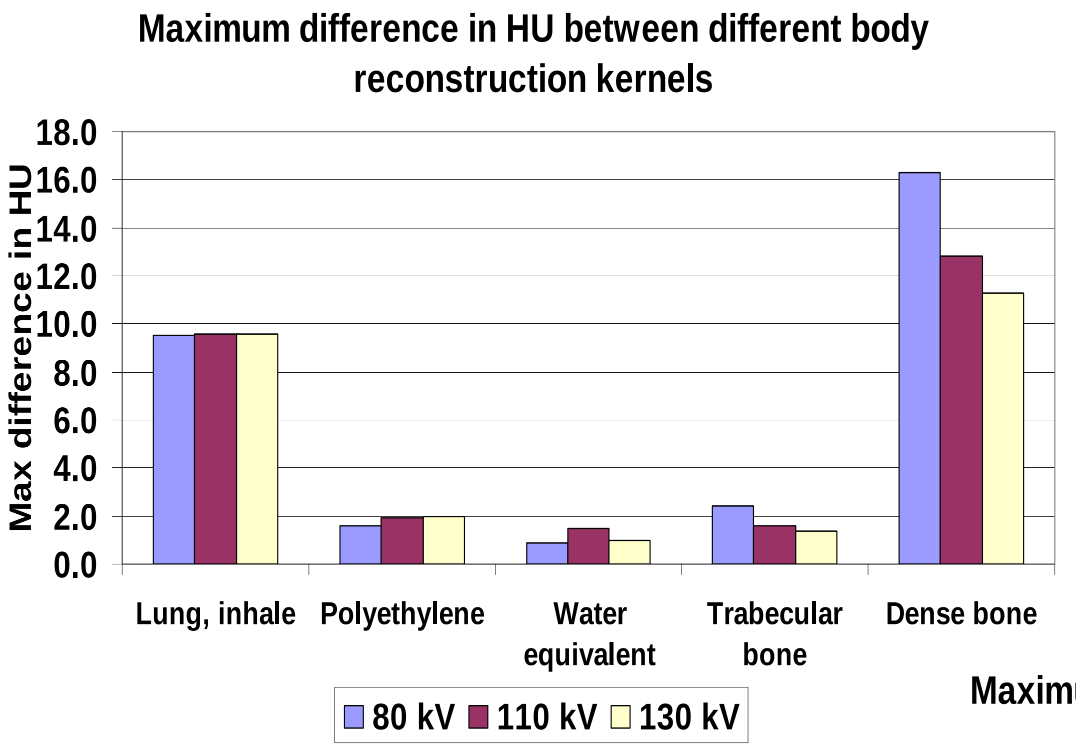
Effect of kernel choice on HU constancy - method

- CT image of ED rods in body phantom
- Circular ROI inside each rod



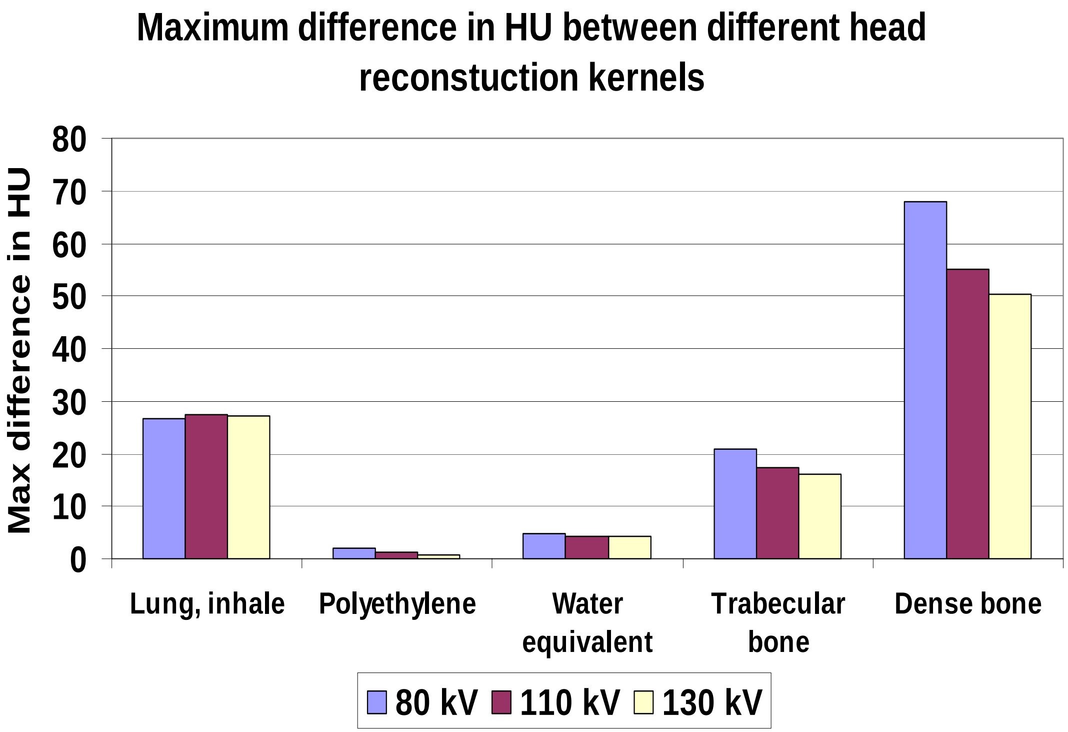
Results

Variation in HU is greater for head reconstruction kernels than it is for body reconstruction kernels



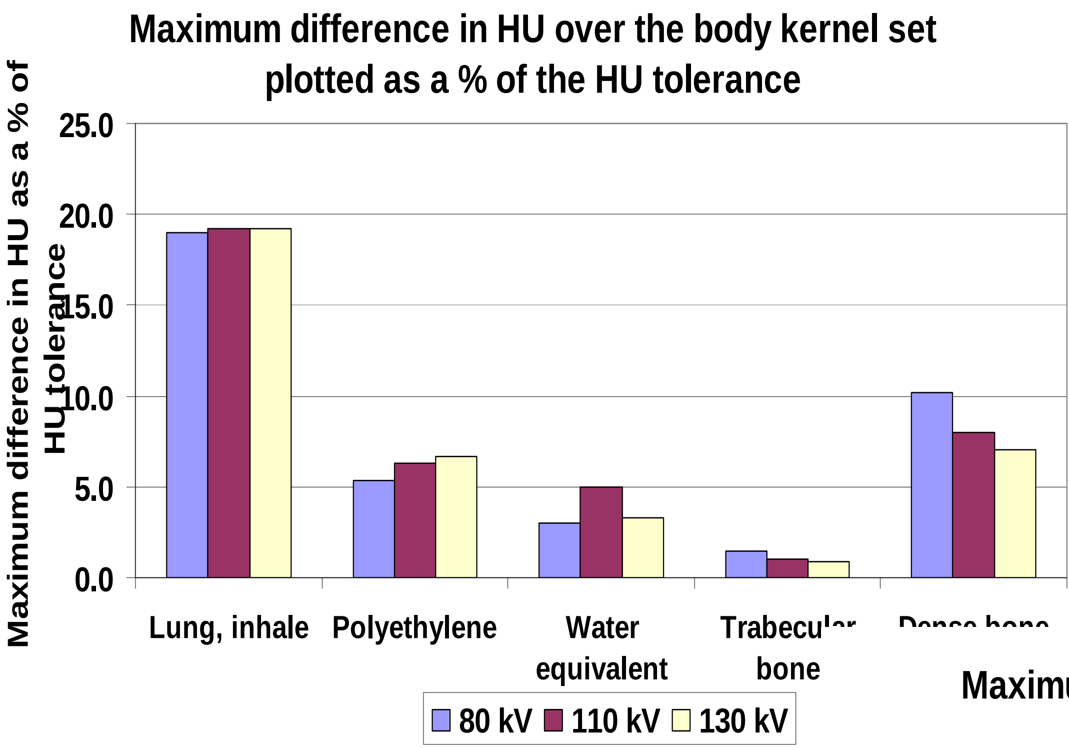
HU variation greatest for materials at extremes of HU scale

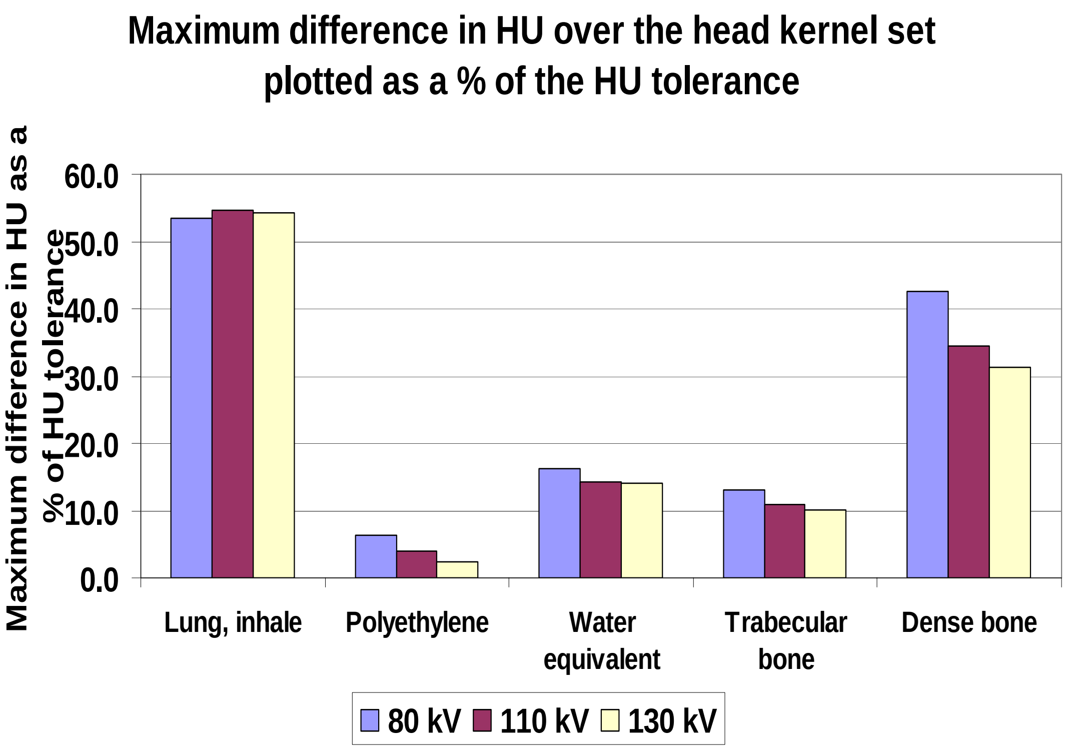
For bone the lower the tube voltage the greater the variation in HU



Results

Range of HU values measured within each kernel set plotted as % of HU tolerances calculated



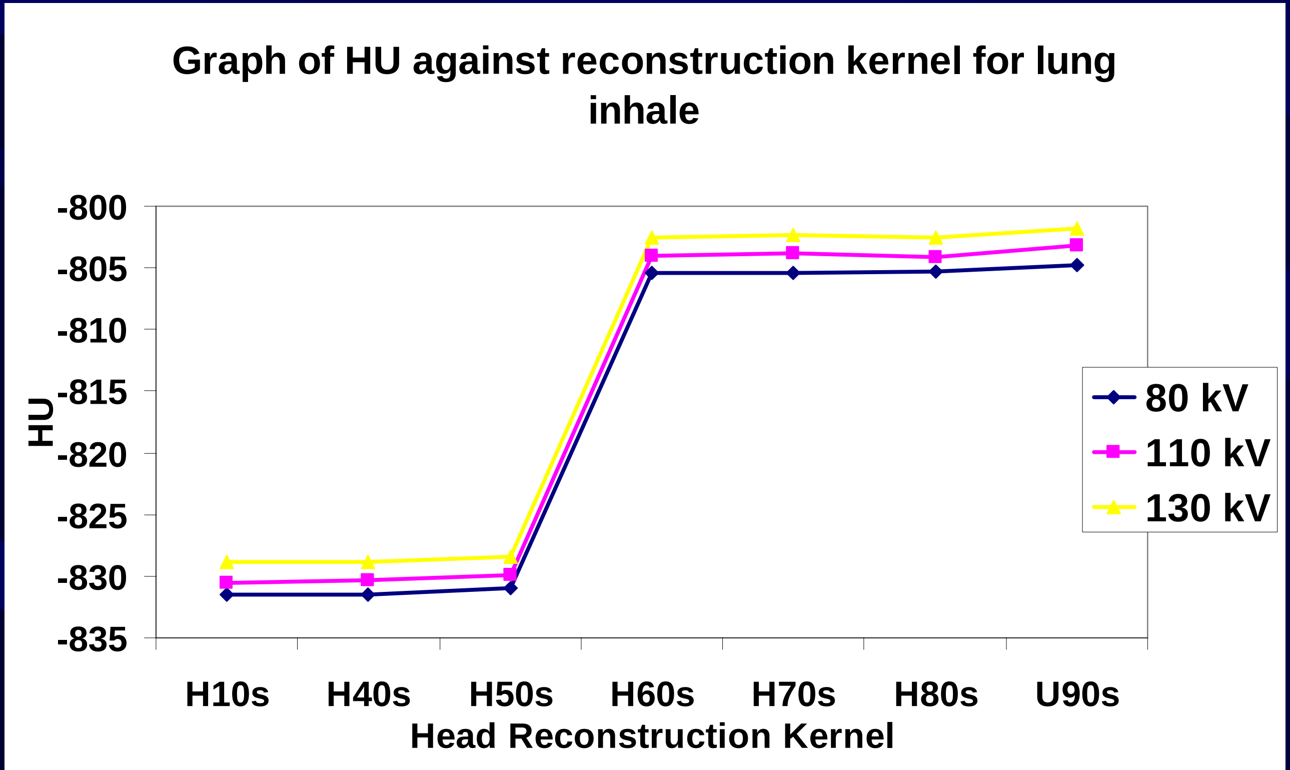


In terms of delivered dose the effect of the variation in HU is worst for lung inhale

In no instance is any tolerance exceeded

Results

- Within head kernel set trend in the HU values
- Sudden change between H50s & H60s kernels
- For lung inhale & water equivalent materials mean HU increased
- For bone mean HU decreased



Post-processing filters

- Low Contrast Enhancement (LCE)
  - – Improves low contrast resolution
  - – Decreases image noise
  - – Four grades
- High Contrast Enhancement (HCE)
  - – Improves high contrast resolution sharpening image
- Posterior Fossa Optimisation (PFO)
  - – Reduces beam hardening artefacts

Effect of post-processing filters on HU constancy - method

- QUASAR body phantom scanned
- Again 80, 110 & 130 kV used
- H40s, H60s & B40s kernels used in turn
- Found mean & SD of Hounsfield values within circular ROI inside each ED rod
- Filters applied & HU values re-measured
- Differences in the mean HU calculated

Results - LCE

- For LCE filter maximum change 4.6 HU (H40s kernel, 80 kV, dense bone)
- In general the lower the kV the greater the effect
- LCE algorithm caused decrease in mean HU for all materials except for dense bone
- Images reconstructed with head kernels were generally more affected
- Those reconstructed with H40s affected most

Results - HCE

- Maximum change 6.0 HU (H40s, 80 kV, dense bone)
- Mean HU values increased in all cases
- HU change less affected by tube voltage
- similar changes observed for all reconstruction kernels used

Results - PFO

- Significantly affected HU values for some materials
- Water equivalent: max change 27.0 HU (H40s, 80 kV) just within 30 HU tolerance
- Trabecular bone: max change 114.4 (B40s, 80 kV) 160 HU tolerance approached
- Dense bone: max change 589.7 HU (B40s, 80 kV) exceeds the 160 HU tolerance
- PFO should not be used clinically

Conclusions

- HU constancy important in treatment planning
- Head reconstruction kernels affect HU constancy more than body kernels
- The effect of the variation with reconstruction kernel is worst for materials at the extremes of the HU scale
- In no case did a change in kernel cause the HU tolerances to be exceeded
- The PFO filter should not be used clinically

Thanks for listening!

Any Questions?