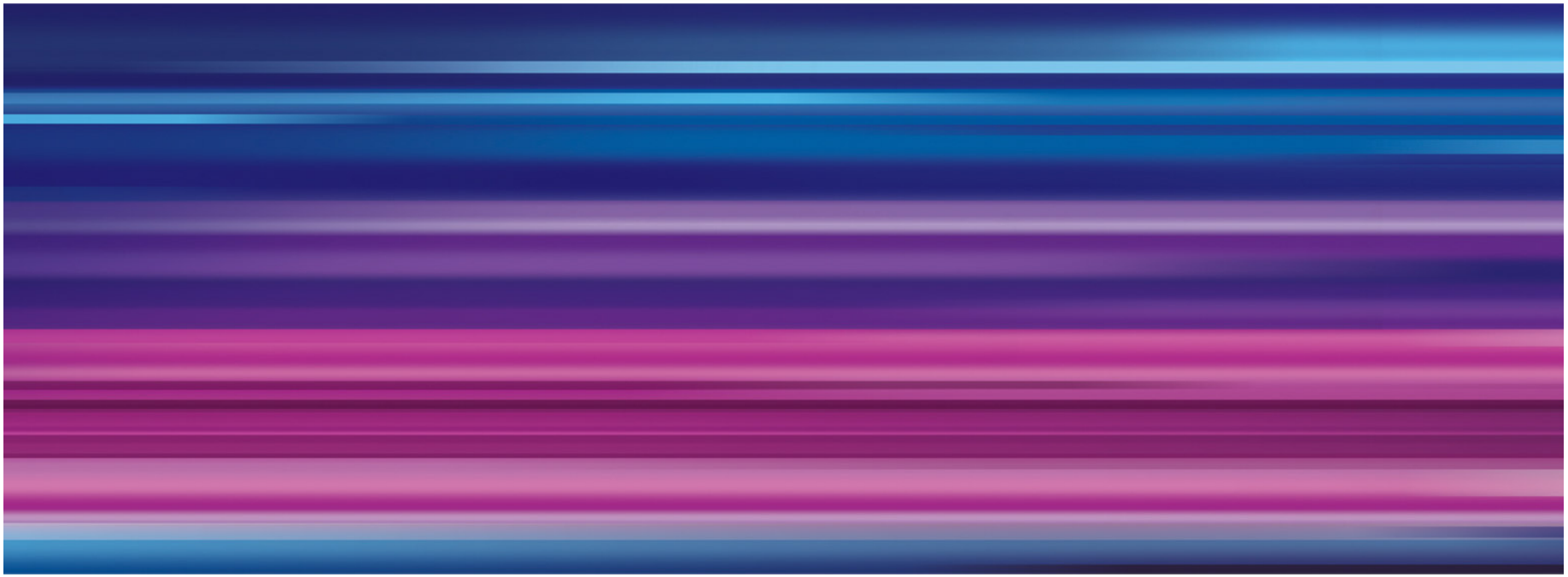
Low dose CT in PET-CT scanning: the impact of varying CT parameters on PET quantification

Nicholas Keat

Imanova Ltd



Radiation dose in research PET-CT

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Often working with healthy volunteers

- No direct benefit from scan

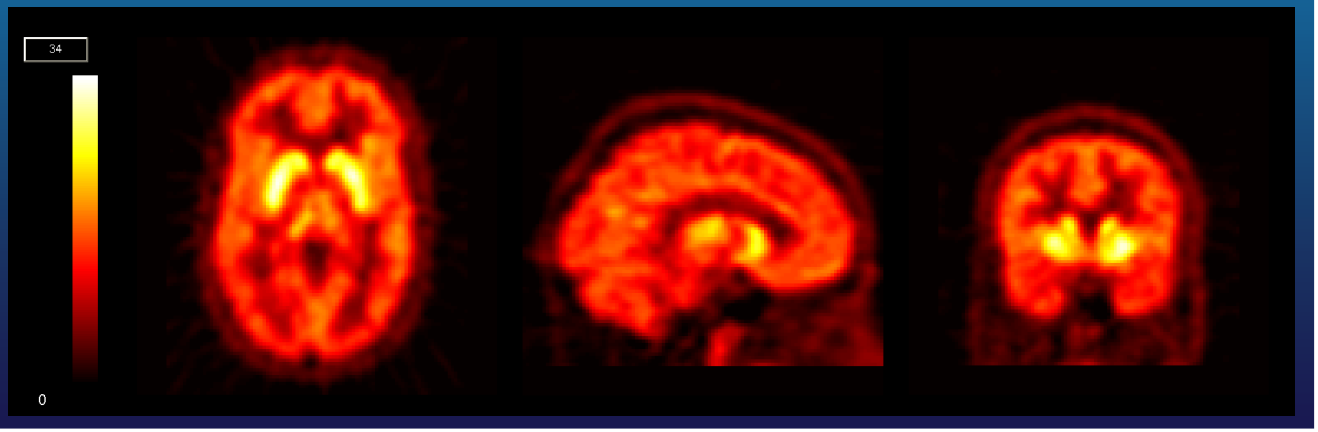
Typical dose constraint of 10 mSv total ED for a study

- Can include 2-3 PET-CT scans

Effective dose from a ‘low dose’ CT scan (Siemens Biograph, AC only, 1 bed position)

- Up to 1.5 mSv for body
- 0.4 mSv for head

Is this optimal?



Factors affecting CT dose

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Main factors that govern ED from CT

- Anatomical location and coverage(sensitive organs)
  - Not a variable for a given study
- X-ray exposure parameters (voltage, current)

Tube voltage

- Affects the energy and intensity of the x-ray beam
- Dose ~ proportional to kV^2

Tube current

- Affects x-ray beam intensity
- Dose proportional to mA

Potential effects of CT dose reduction and experimental questions

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Increase in CT noise => increase in PET noise

Artefacts in CT image (photon starvation) => artefact in PET image

Shift in CT number at different kV => PET bias

Can we simulate and quantify these changes?

How does dose reduction by changing kV and mAs compare?

Is there a minimum limit on CT dose – how low can we go?

Experimental setup

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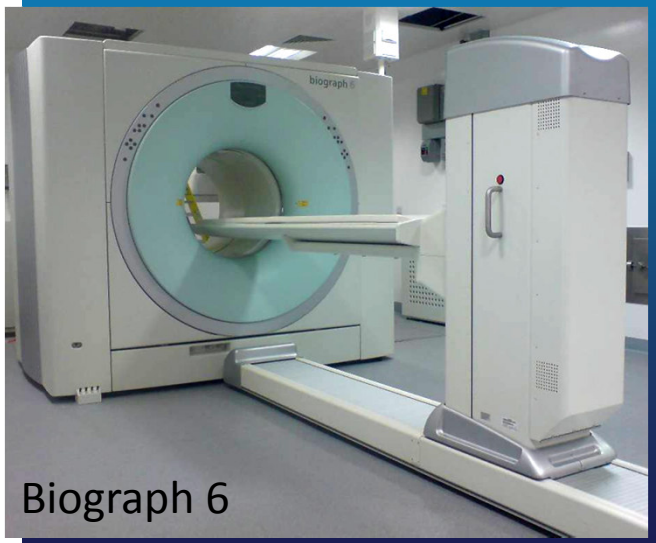
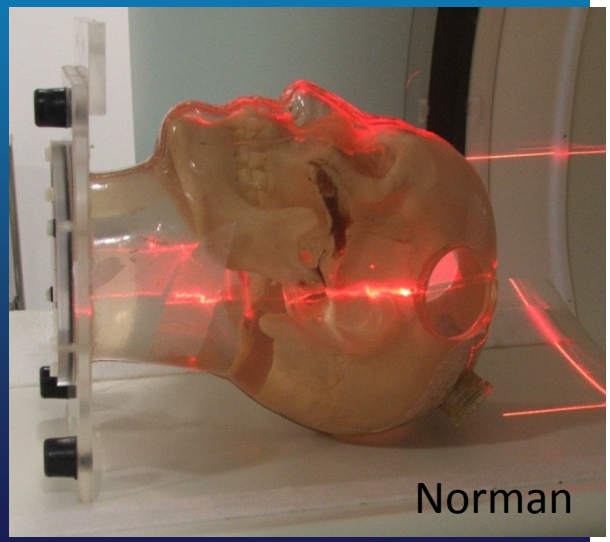
Siemens Biograph 6 TruePoint / TrueView

- LSO crystals, 162/216 mm axial FOV, 6 slice ‘Emotion’ CT scanner
- Abdomen phantom with spine, lungs, liver
  - Add on Teflon ‘arm’ bone
- Skull phantom ‘Norman’ (thanks to RMH, Sutton)



Biograph 6


Abdomen phantom


Norman

Experimental setup: scanning

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Repeat CT at different kV/mAs settings

- 80, 110, 130 kV
- 8, 10, 15, 20, 30, 200 mAs
- Siemens standard AC only setting is 130 kV, 30 mAs
- 130 kV, 200 mAs used as ‘reference’ image

Acquire list mode PET images of phantom (1 hour)

- Reconstruct using each CT series for AC

Results – CT images

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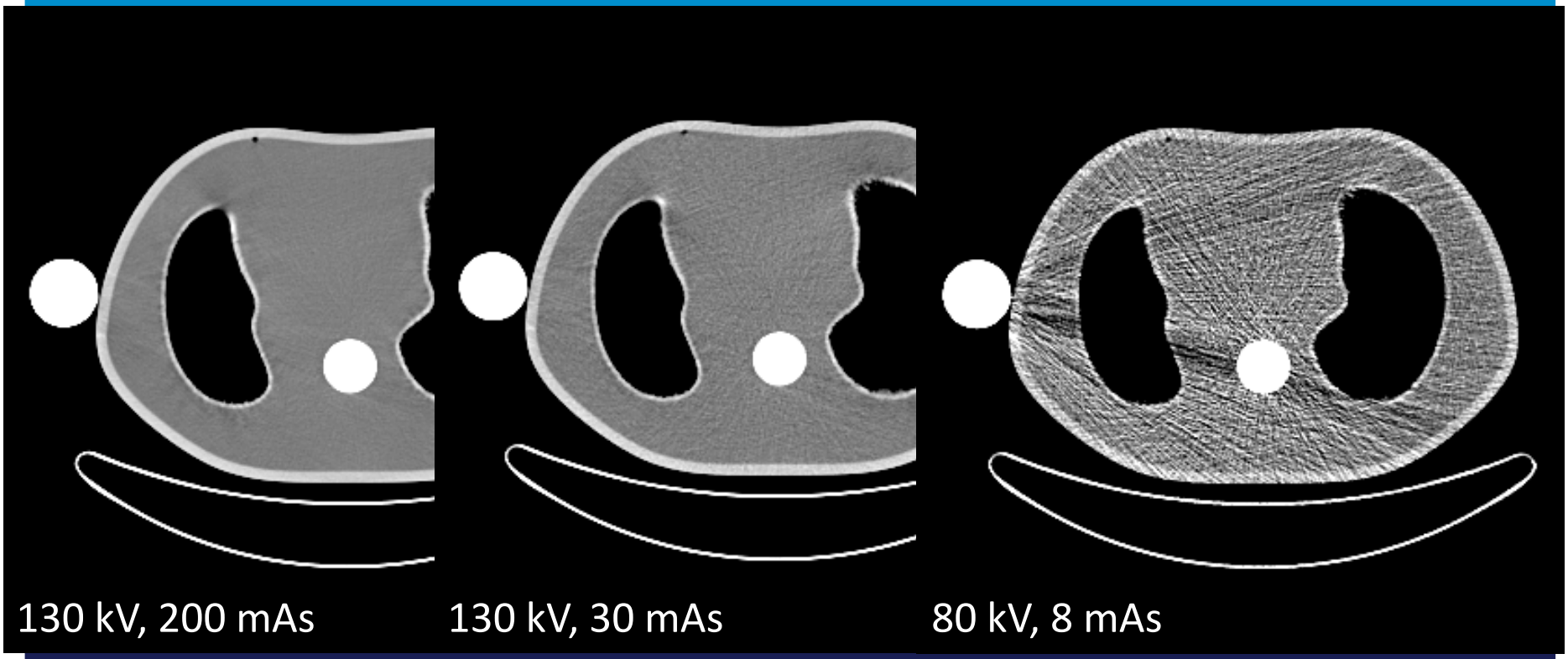
CT images at reference, standard and lowest setting



Results – PET images

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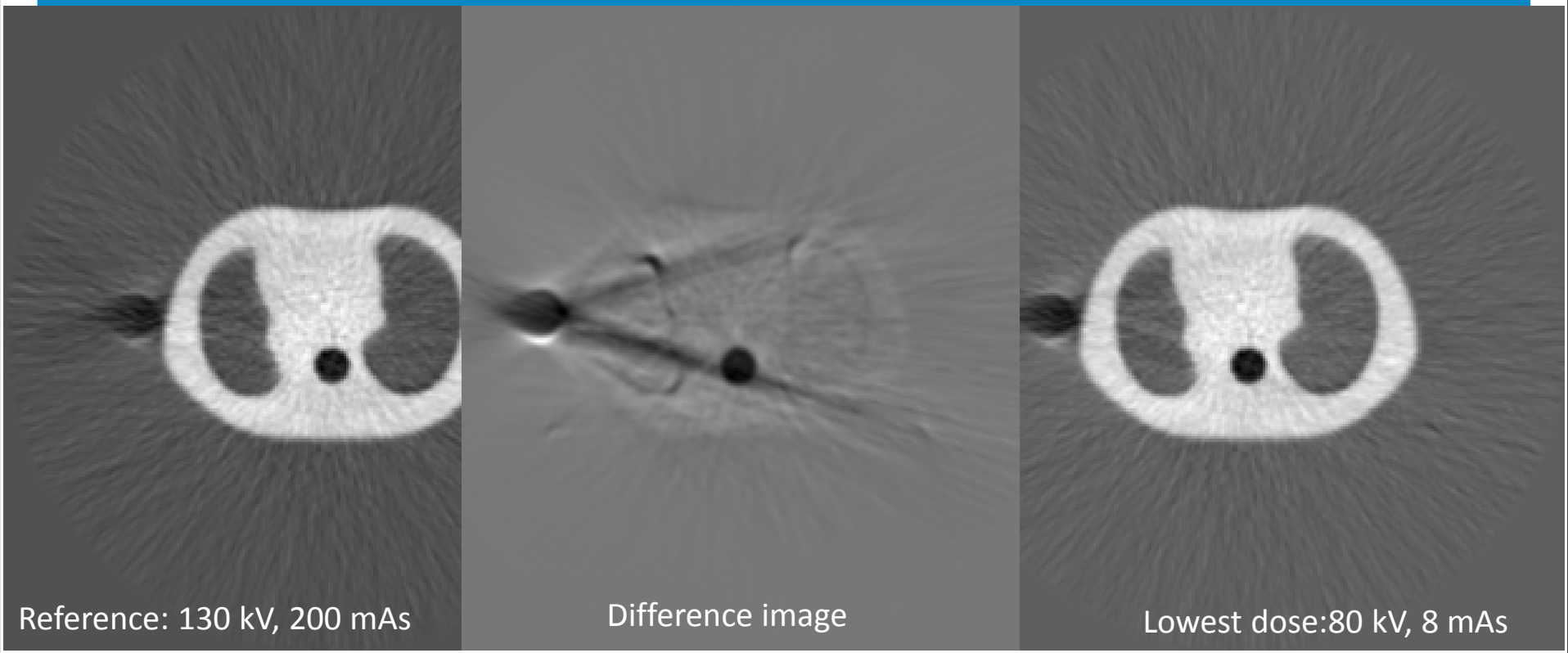
PET images at same point from 1 hour scan

- FBP reconstruction, 5mm Gaussian filter

Spot the difference?



Results – Analysis

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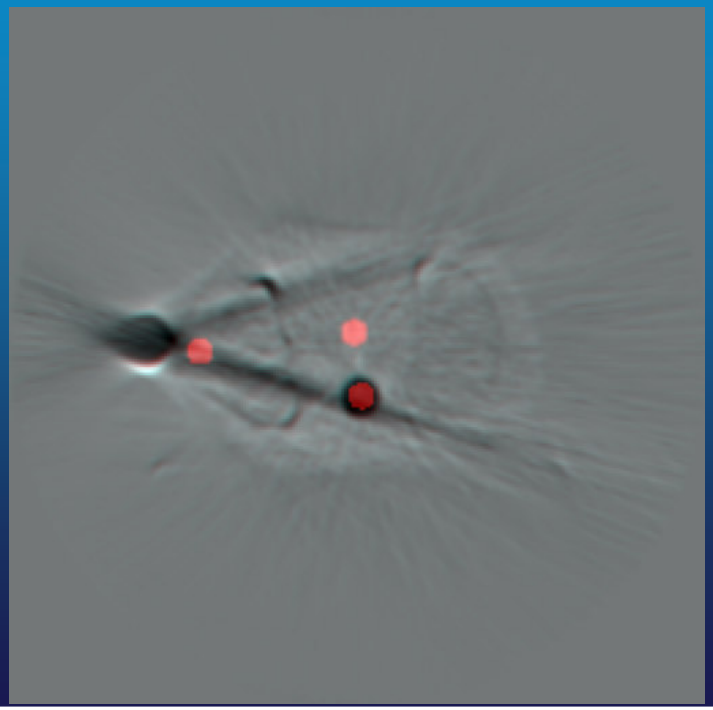
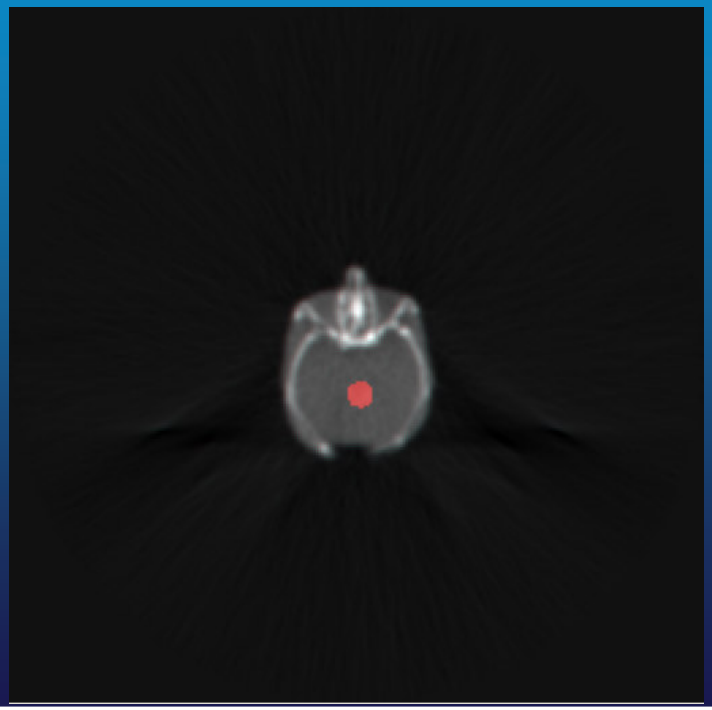
ROIs – centre phantom, near arm and in spine for body

- Calculate mean and SD for each ROI
- Mean of 20 (10 in head) images in middle of phantom
- Analysis for each PET data set





Results – PET noise vs. relative CT dose

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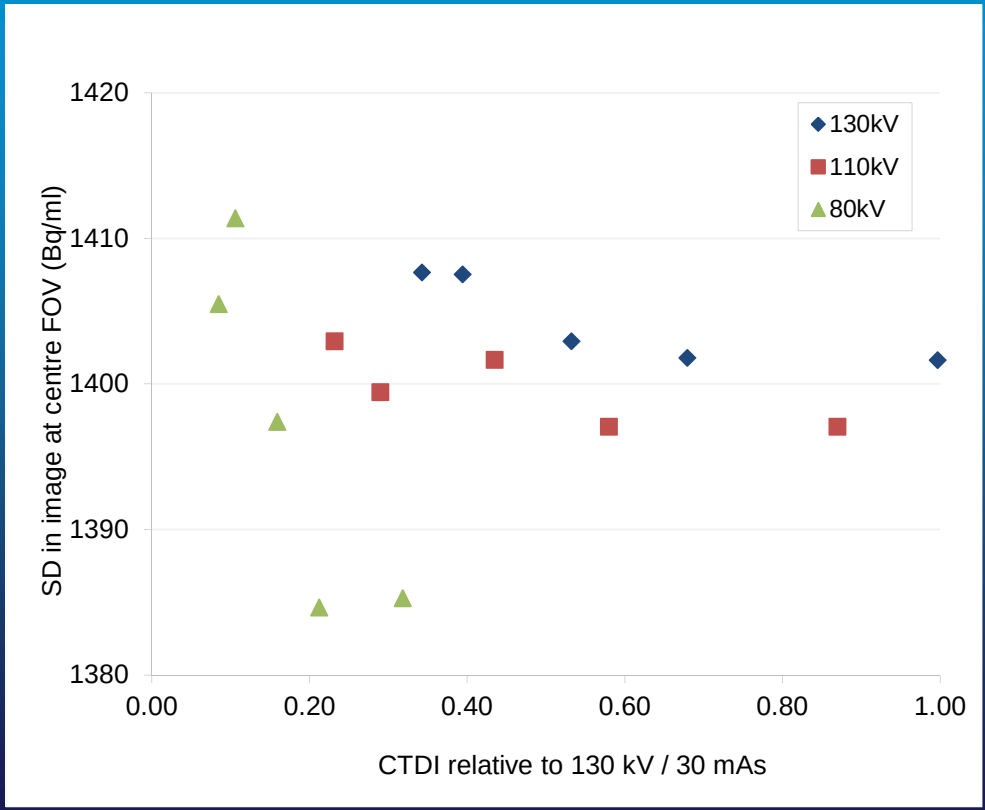
PET image SD vs. relative CTDI, 5 min scan, centre of image

– Difference < 10 Bq/ml (0.7%) for 110 & 130 kV



Results – PET pixel bias vs. relative CT dose

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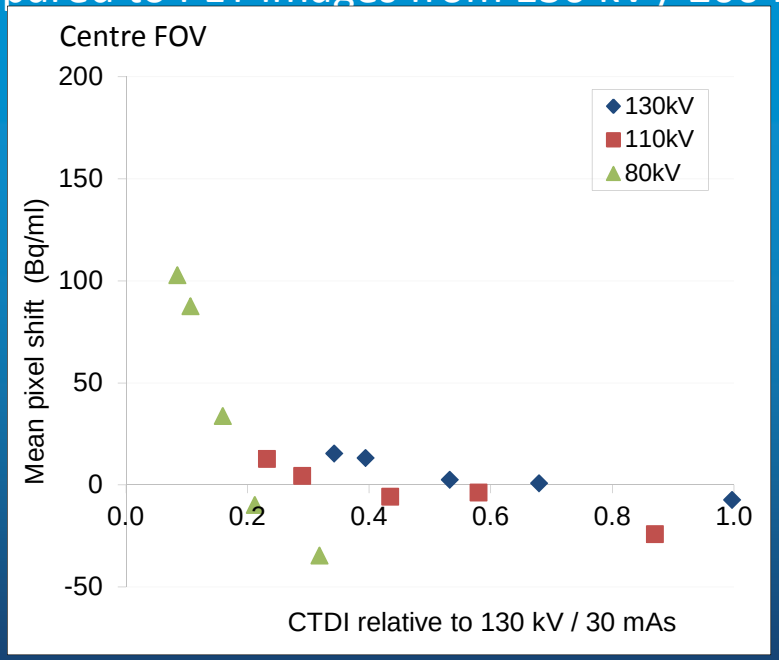
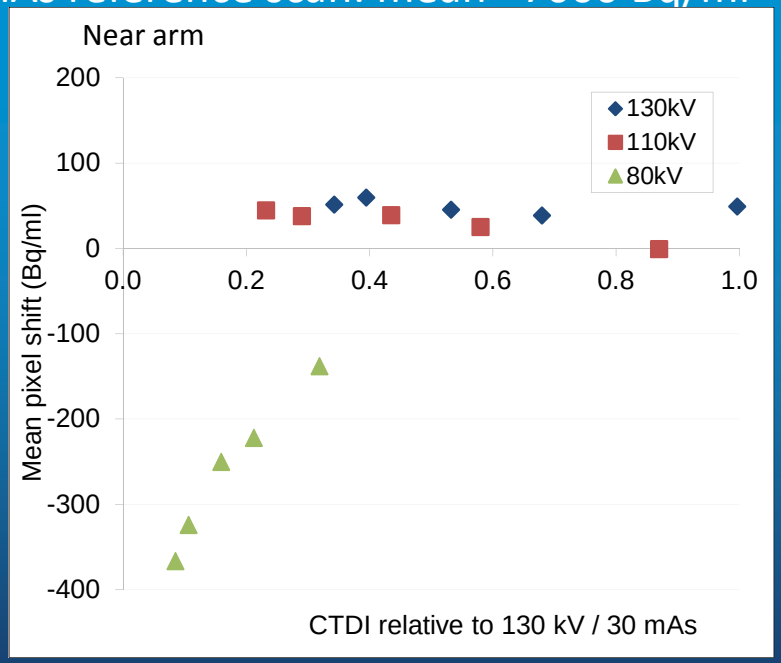
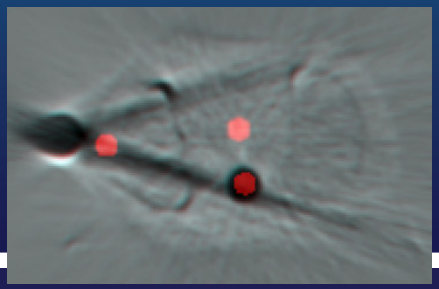
Compared to PET images from 130 kV / 200 mAs reference scan: mean ~7000 Bq/ml





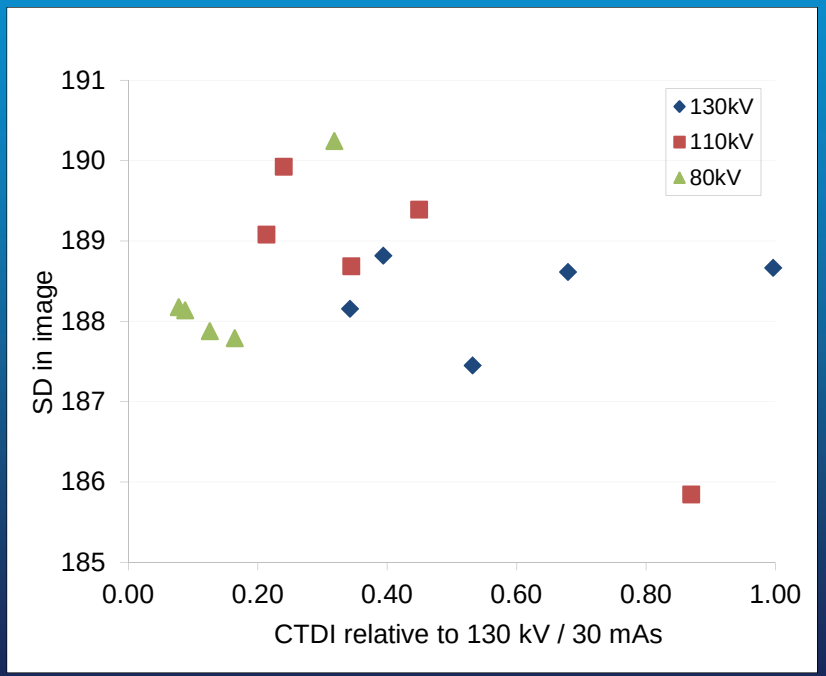
Pixel bias (kBq/ml)	80 kV	110 kV	130 kV
Centre FOV	< 100 (1.5%)	< 25 (0.3%)	< 15 (0.2%)
Near arm	< 400 (5%)	< 50 (0.7%)	< 60 (0.9%)

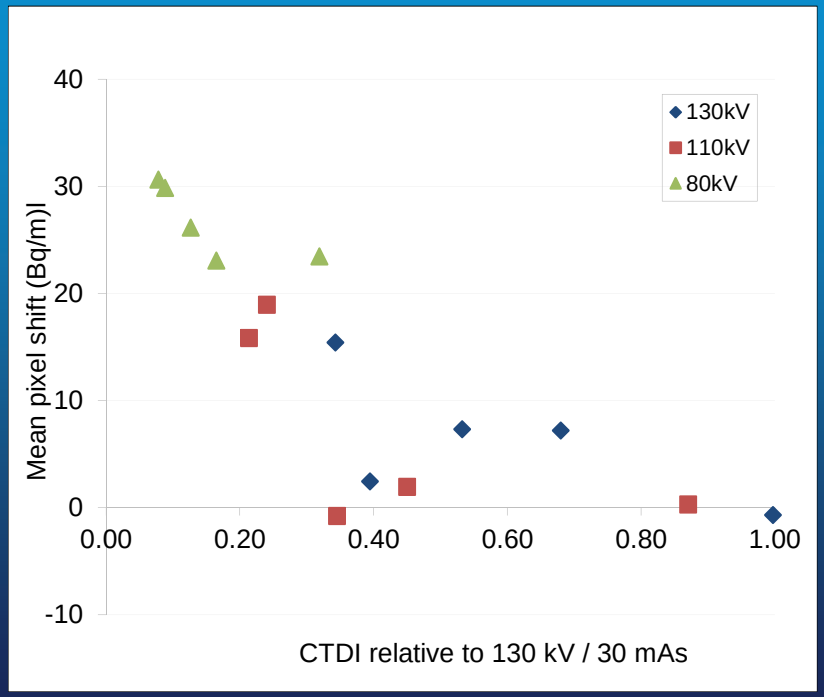


Results – head images

PET pixel SD and bias from reference images vs. relative CTDI (mean conc. 5500 Bq/ml)

- SD and bias differences smaller than for body





Context – effect on dose constraints

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CT dose reduction of ~ 75% by reducing mAs alone

- 1.1 mSv for body, 0.26 mSv for head
- Little effect upon image quality

If limited by dose constraint, could 'spend' CT dose reduction on increased PET activity

- For 2 scans, 10 mSv protocol could increase PET activity by 30% (body) or 3% (head)

CT dose reduction of further ~ 75% (body) and 60% (head) by kV reduction

- IQ difference becomes more significant

Conclusion

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For AC only scans, dose can be reduced significantly

Minimal effect on PET SD by changing kV and mAs

Slight bias from reducing kV

- Minimal bias from reducing mAs

ED reduction from low dose scans much more significant for body than head

Reduced mAs technique sensible for body imaging

- If it is truly AC only

Results valid for Siemens scanners

- Not necessarily the case for GE/Philips