United Lincolnshire Hospitals NHS
NHS Trust

First Experiences with the Mercury 4.0 AEC Phantom

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Overview

- An optimisation problem
  - Optimisation problem (Radiotherapy CTSIM)
  - Optimisation without an AEC phantom
  - AEC setup and Optimisation with the Mercury 4.0 AEC Phantom
- First impressions of the Mercury 4.0 AEC Phantom

An Optimisation Problem

Two cervix brachytherapy scans:

- Planning scan
- Verification scan
  - immediately after surgical insertion of applicator to verify positioning

Complaint:

- for some patients the verification scan is noisier (too noisy?) than the planning scan

Optimisation with no AEC Phantom

Cervix Brachy	Acquisition and AEC Settings				Reconstruction Settings		
	Rotation Time (s)	mA floor	mA ceiling	Target SD	Slice Thickness	Increment	Noise Reduction
Planning scan	0.75	80 mA	480 mA	12.5	3 mm	3 mm	IR
Verification scan	0.5	80 mA	500 mA	12.5	2 mm	2 mm	Non IR

To reduce noise in verification scans:

- ↑verification slice thickness to 3mm
- ↓ slice increment to 1.5 mm to preserve spatial resolution

Should also reduce dose in the verification scans:

- Switch on iterative reconstruction
- ↓ Effective mAs required to achieve the target SD

And why not also increase rotation time from 0.5 to 0.75s?

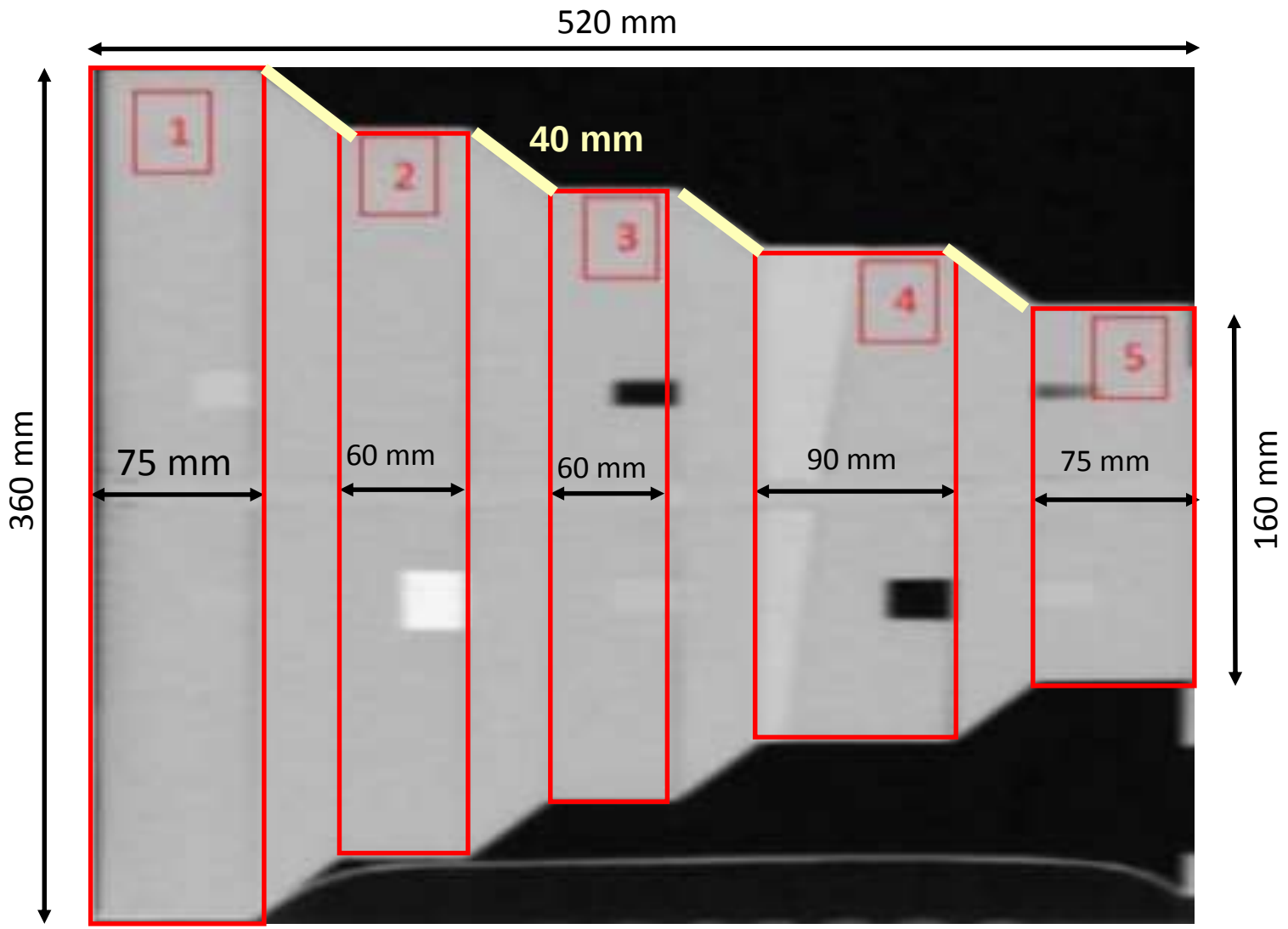
RANDO Phantom

We scanned our RANDO Phantom (AEC can't cope with water phantoms) to check our optimisation:

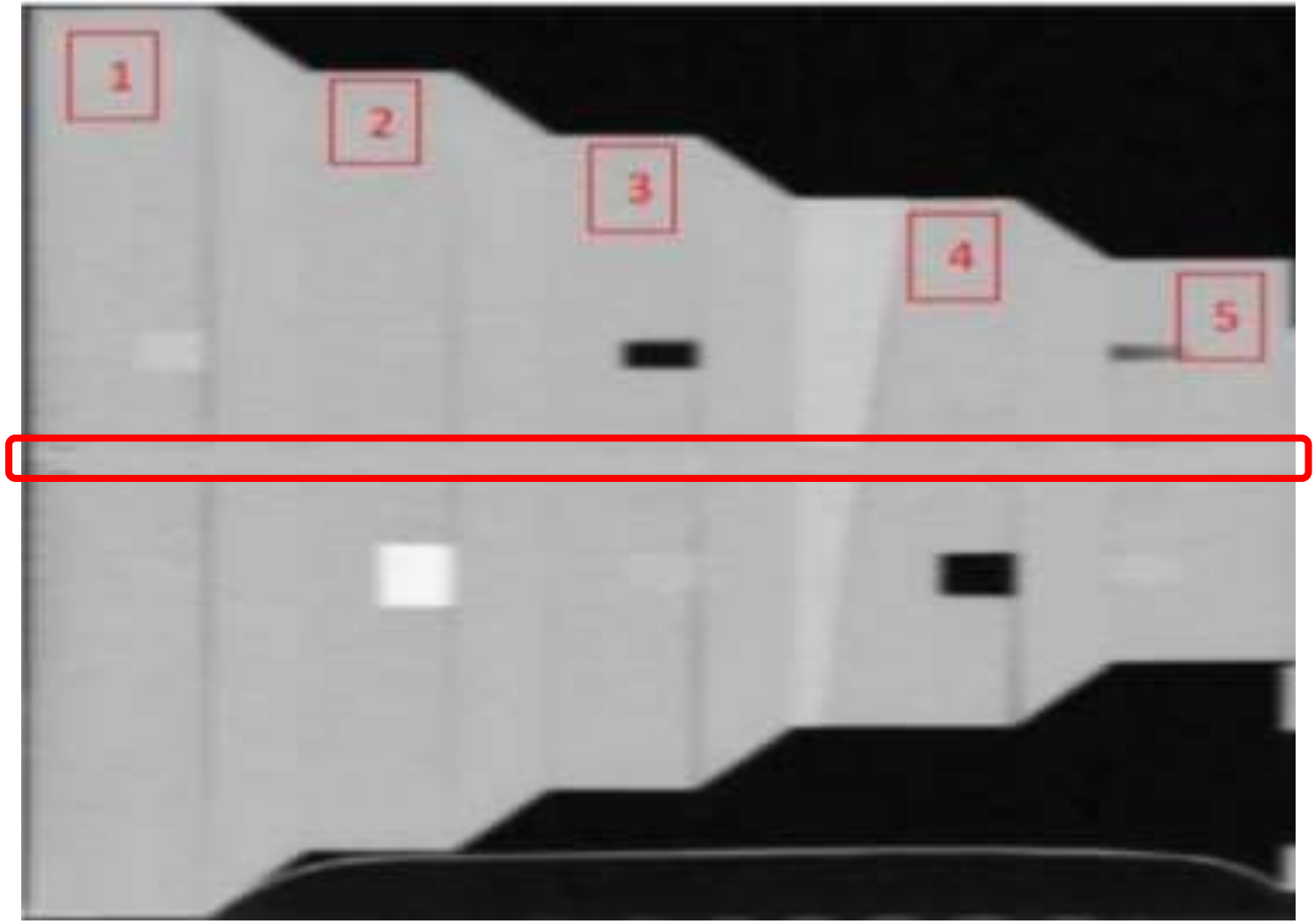
- Noise was indeed higher in the original verification scan than in the planning scan
- Noise and dose didn't change with protocol adjustments as expected
- The mA set by the AEC was 'floored' for most of the planning and optimised verification scans
- We need to sort out the AEC before optimising!

Mercury 4.0 AEC Phantom

AEC Performance Modules



AEC Performance Modules

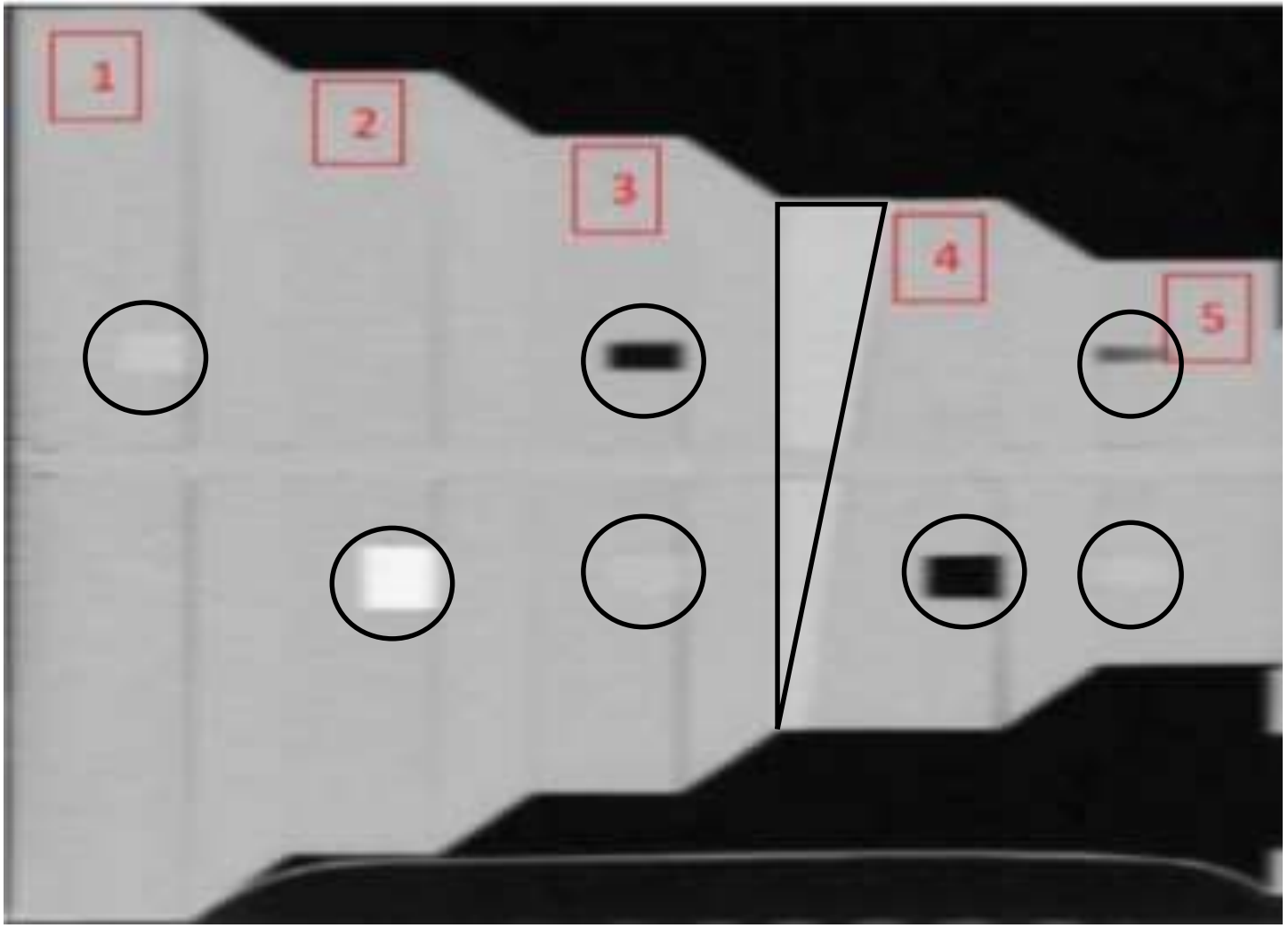


AEC Performance Modules

Section	Physical Diameter (cm)	WED @ 120kV (cm)	Equivalent BMI (kg /m^2)	
			Thorax	Pelvis Abdomen
1	36	34.8	43 (severely obese)	36 (severely obese)
2	31	29.9	32 (obese)	27 (overweight)
3	26	25.3	20 (normal)	18 (underweight)
4	21	20.6	10	9
5	16	16.0	paediatric	paediatric

Under weight: 16 – 18.5
Normal weight: 18.5 – 25
Over weight: 25 – 30
Obese: 30 – 35
Severely obese: 35 - 40
Morbidly obese: 45+

AEC Image Quality Inserts



AEC Image Quality Inserts

For size dependent image quality evaluation each section contains contrast inserts:

- solid water
- Bone
- Polystyrene
- 10mg/L iodine
- Air

Section 4: 10^{o} solid water ramp for z-axis MTF

AEC Image Quality Inserts

Comes with software for image analysis[1]

- Noise and Noise power spectrum
- Uniformity
- MTF
- Task Transfer function based on model observer
- Detectability index

1 Wilson, J. M., Christianson, O. I., Richard, S., & Samei, E. (2013). A methodology for image quality evaluation of advanced CT systems. *Medical physics*, *40*(3).

METHOD

- Scan the AEC Phantom using the original planning, original verification and modified verification protocols

- For each reconstructed slice obtain
  - z-location (DICOM)
  - mAs (DICOM) and hence mAs_{eff} = mAs/pitch
  - SD in an annular (to avoid the rod) ROI

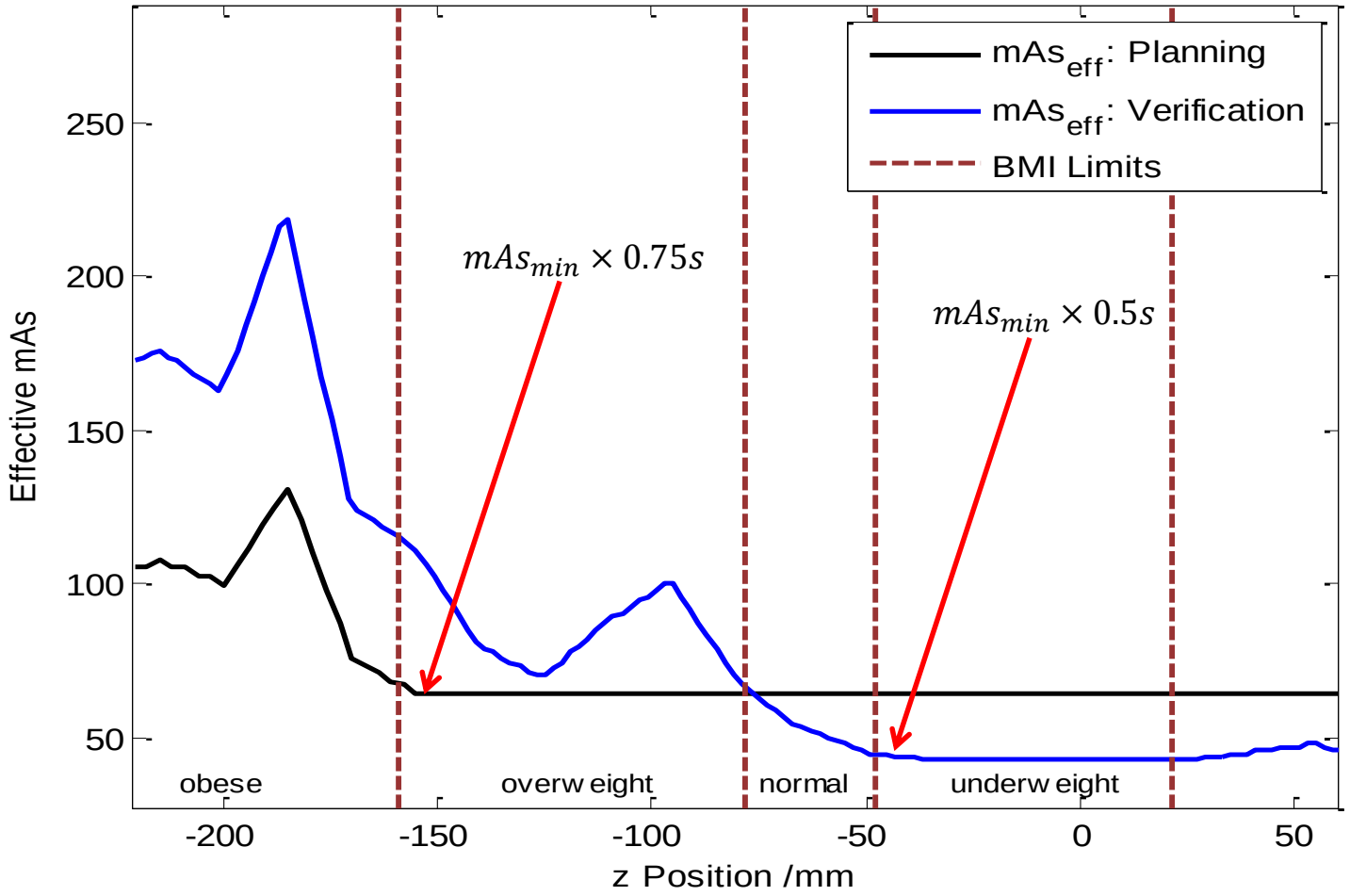
AEC Performance Evaluation

- Using the known phantom WED(z) at 120kV divide the scan into four BMI (pelvis) regions[2]:
  - Obese
  - Overweight
  - Normal
  - Underweight

- Determine which BMI's the AEC 'works' for (BMI regions where mAs_{eff} > mAs_{eff} floor)

2 Menke, Jan. "Comparison of different body size parameters for individual dose adaptation in body CT of adults." *Radiology*236.2 (2005): 565-571.

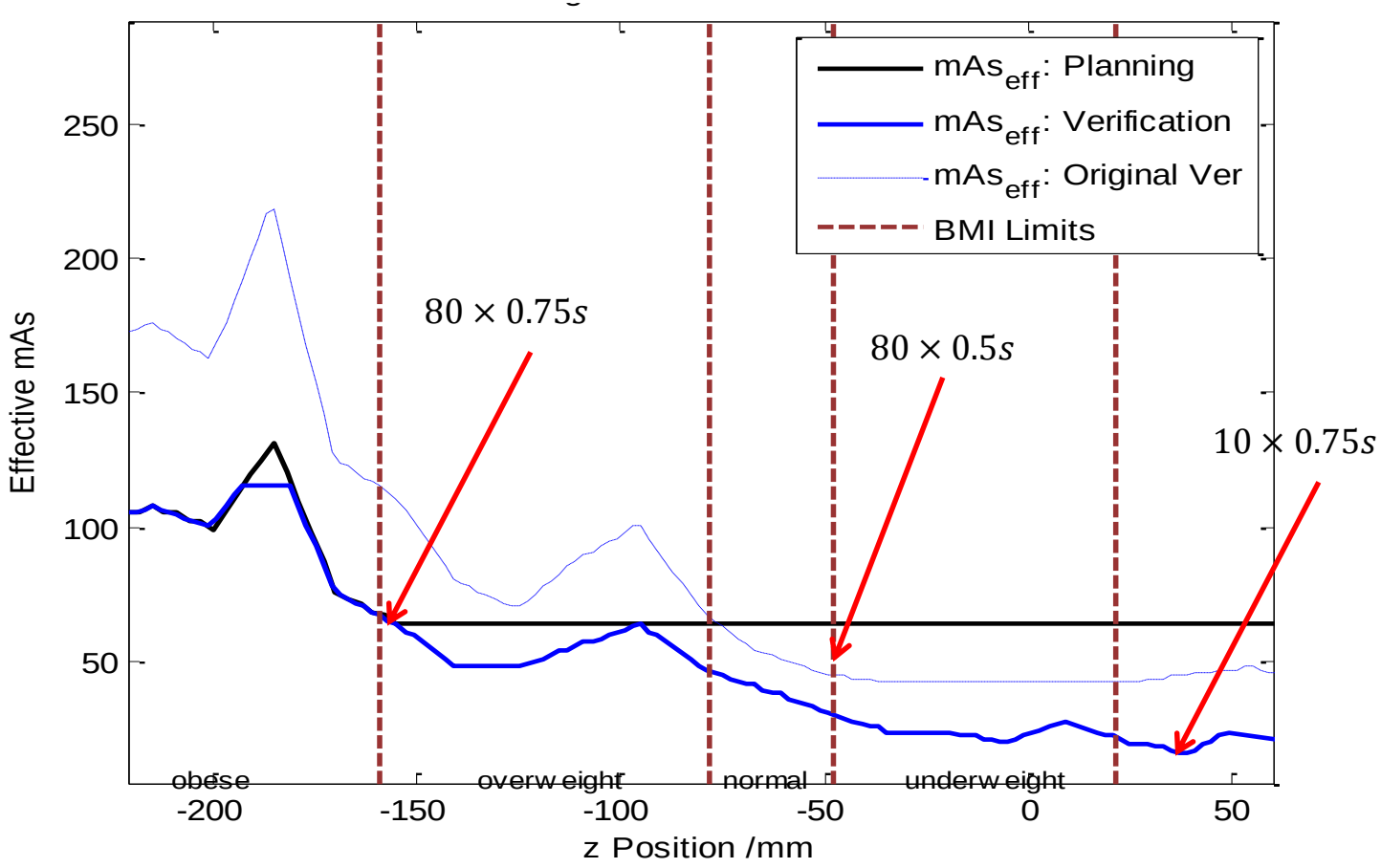
AEC Performance Evaluation: Original Protocols



AEC effectively disabled in the original planning scan (and 'optimised' verification scan)

AEC Performance Evaluation:

Effect of lowering the mA Floor



It was easy to evaluate the effect of adjusting the AEC setup (here lowering the mA floor) on AEC performance

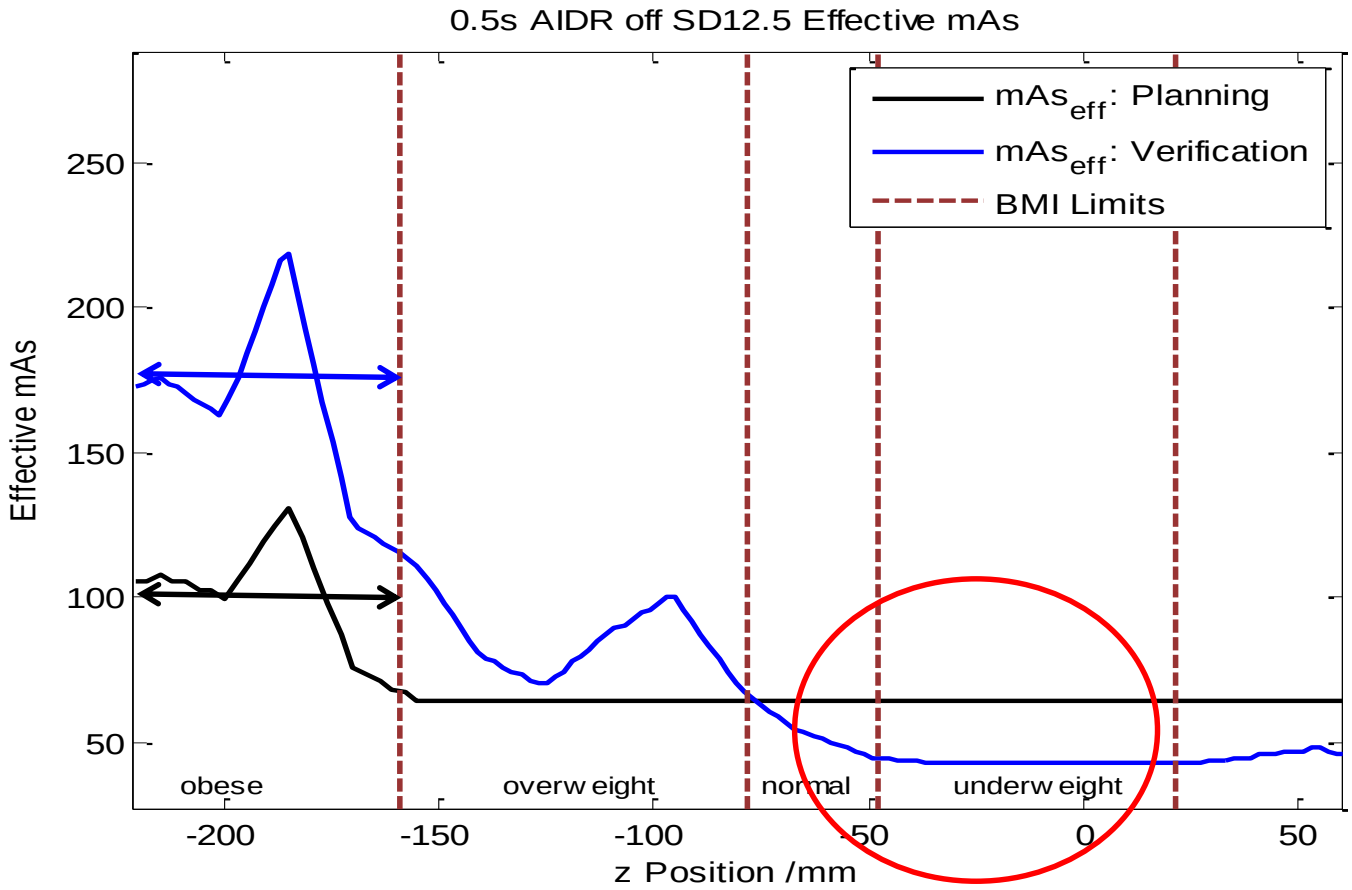
Dose and Noise Evaluation

For protocol optimisation evaluation:

- For each BMI category calculate
  - Mean effective mAs (a proxy for $CTDI_{vol}$)
  - Mean noise

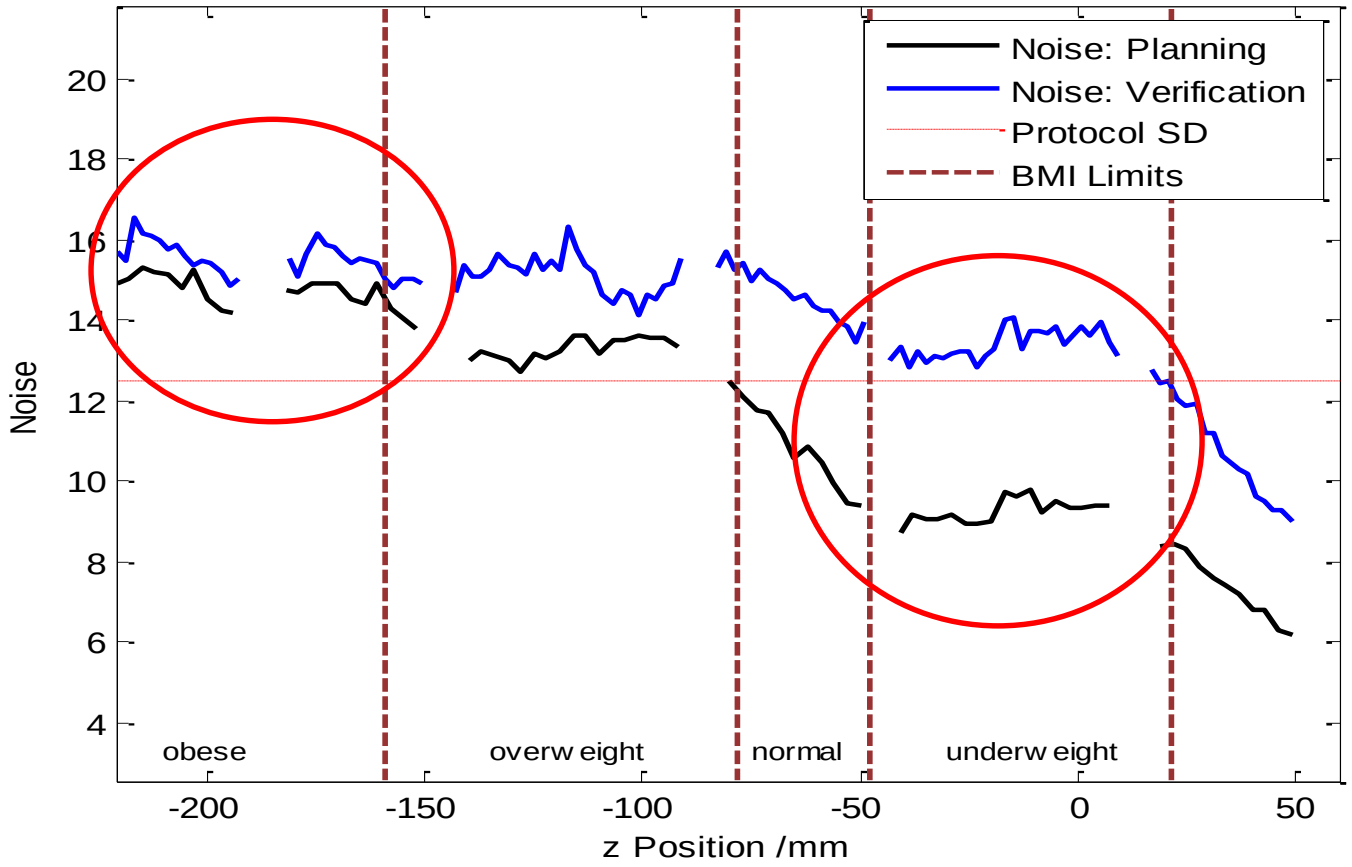
- Hence evaluate the impact of protocol changes on patient dose and image quality

Dose Evaluation: Original Protocols



Get the mean effective mAs over each BMI category….. verification scan doses are much higher for obese patients (no IR) but lower for small patients (verification scan mA has ‘floored’)

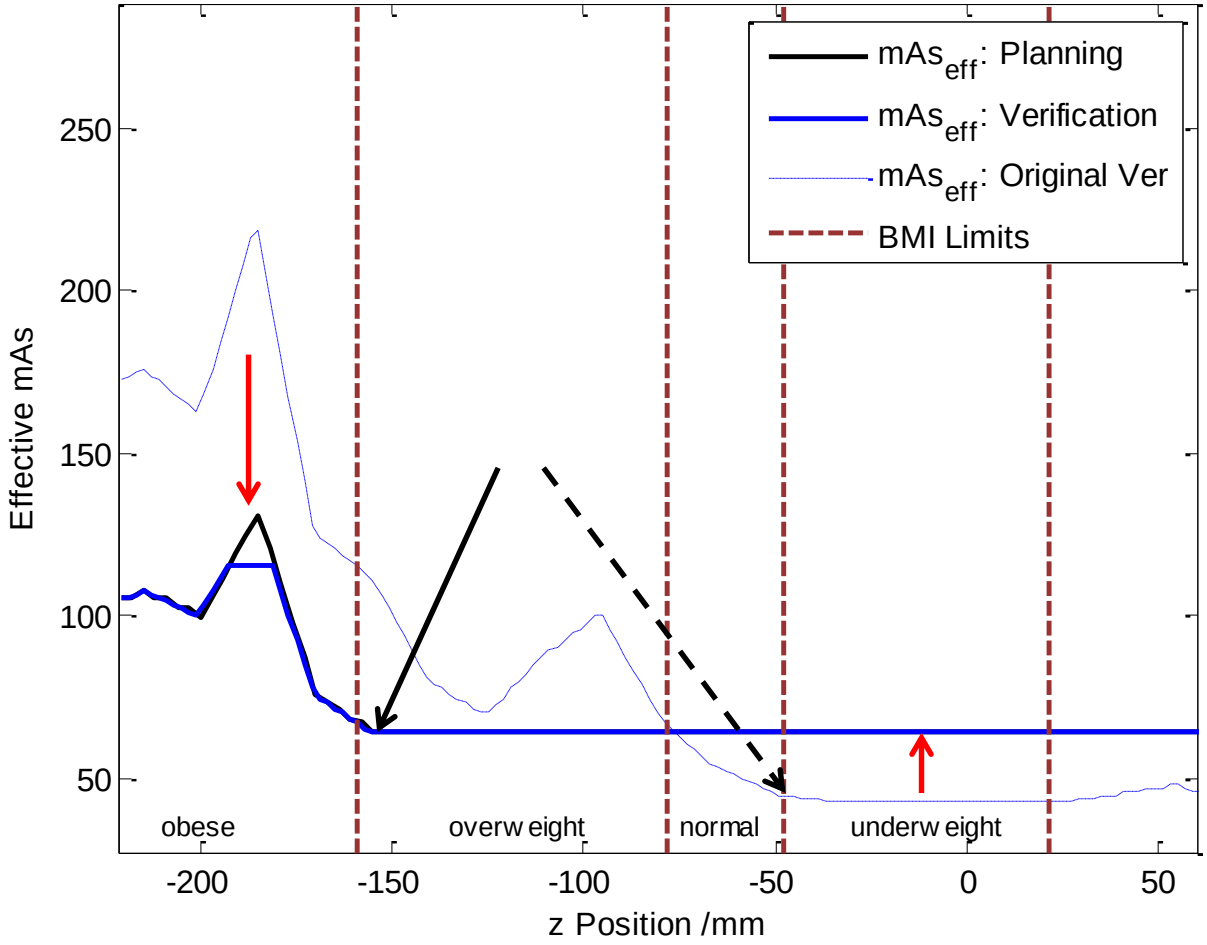
Noise Evaluation: Original Protocols



Get the mean effective SD over each BMI category…..noise in the verification scan is indeed higher for small patients (dose is lower) BUT similar to the planning scan for obese patients (dose much higher)

Optimisation evaluation:

Effect of switching on IR



It was easy to evaluate the effect of adjusting the protocol (here switching on IR) on AEC performance and patient dose (and noise)

Summary

- Could evaluate the impact of changes to the AEC and protocols on AEC performance, noise and dose across a large range of patient sizes
- Possibility of resolving our protocols into ‘large patient’ and ‘small patient’ versions
- Further size dependent protocol Optimisation using the IQ inserts?

First Impressions: Cons

The Mercury 4.0 phantom is not perfect :

- Circular, not elliptical cross section – does this matter?
- The IQ inserts affect the AEC (this wasn't evident in the white paper, but is evident in our results… why…)
- Two people needed to lift it into/out of a car

First Impressions: Pros

The Mercury 4.0 phantom

- Proved very useful in solving an optimisation problem – we now have a waiting list for it
- Image quality inserts and analysis software sound particularly interesting
- Taught me how our AEC actually works
- Can be assembled on the couch (manual handling)
- Seems very stable despite the slender plastic connecting rod holding it together
- Was easy to setup

Thanks for listening

Any questions?