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Six years of AEC testing – what have we learned?

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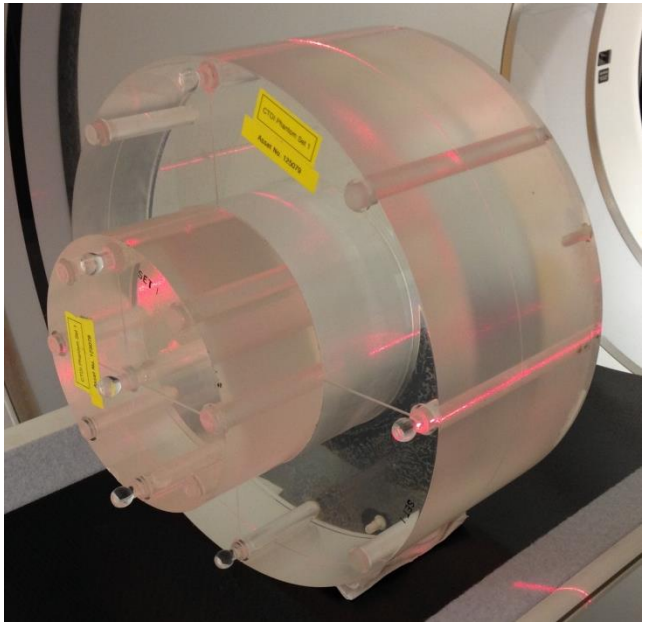
Why test AEC?

- Used for vast majority of clinical scans
  - Including Radiotherapy and Nuclear Medicine CT
- Used to specify required image quality/delivered dose
  - Major determinant of patient dose and clinical image quality
- Potential for non-diagnostic images/over-dosing if system fails

Rationale for the phantom used

- For routine QA tests we take:
  - Raysafe X2
  - Catphan 600
  - Head CTDI phantom and body annulus
  - Laptop
- Didn’t want to carry any additional equipment
- Offset head phantom within body annulus to create three part phantom



Potential phantom issues?

- It is not elliptical
  - No rotational attenuation changes
- It is uniform PMMA
  - Cannot assess any CT number changes if AEC kV changes
- It has large step changes in attenuation
  - Not clinically representative attenuation variation

- Park these for later…

Which performance metrics?

- AEC systems select mA and in some cases kV
- Therefore record
  - Selected kV
  - Average mA (mAs) for scan
  - mA profile along phantom
  - Average CTDIvol for scan (DLP)
- AEC systems are trying to deliver a “specified image quality”
  - Measure noise in each image
  - Plot a noise profile along phantom

Testing Method: Protocol Selection

- Set up dedicated Physics AEC scan protocol
  - Based on clinical Thorax or Abdomen scan protocol
  - Use auto kV selection where available
  - If protocol has min/max mA settings, adjust these and the AEC control parameter to ensure that mA does not reach min or max in any of phantom sections
  - Define helical scan length within protocol
  - Record other AEC settings – e.g. CARE Dose 4D adaptations
  - Reconstruction:
    - 5mm images, 50% overlapping
    - 350mm DFOV
    - Soft tissue recon kernel
    - Use iterative reconstruction where possible

Testing Method: Scanning Technique

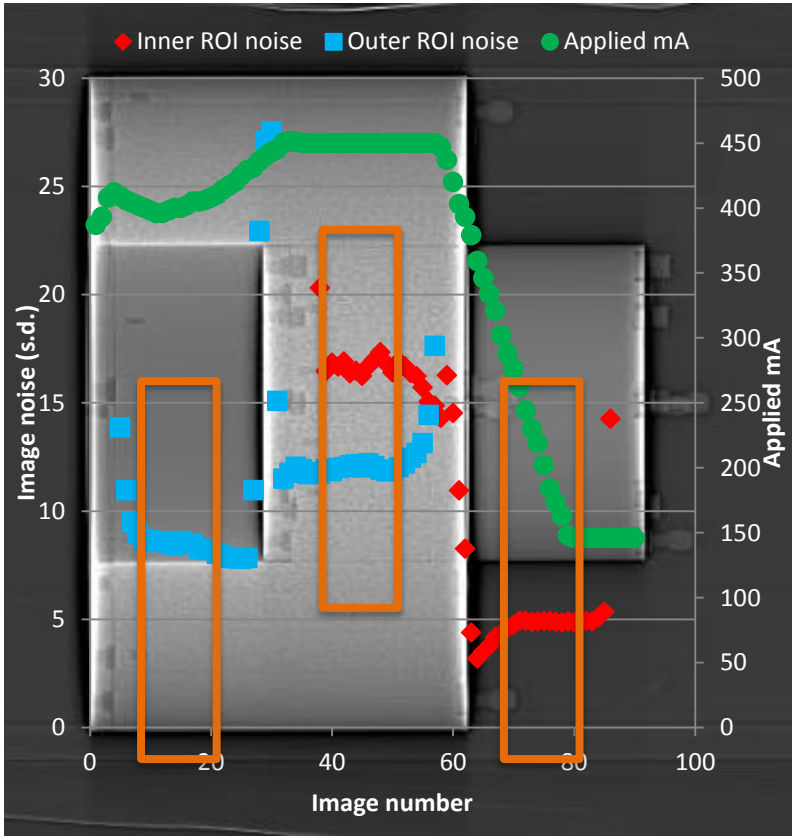
- Carefully centre phantom in gantry
  - Ensure it is level
- Perform planning scan(s)
  - Constrain helical scan to physical length of phantom
    - Thus whole mA range can be used in the phantom, not in air
- Undertake one helical scan
  - Repeat scans performed as required
  - At acceptance perform further scans to fully test AEC system
- Record post scan average mA (mAs), CTDIvol, DLP

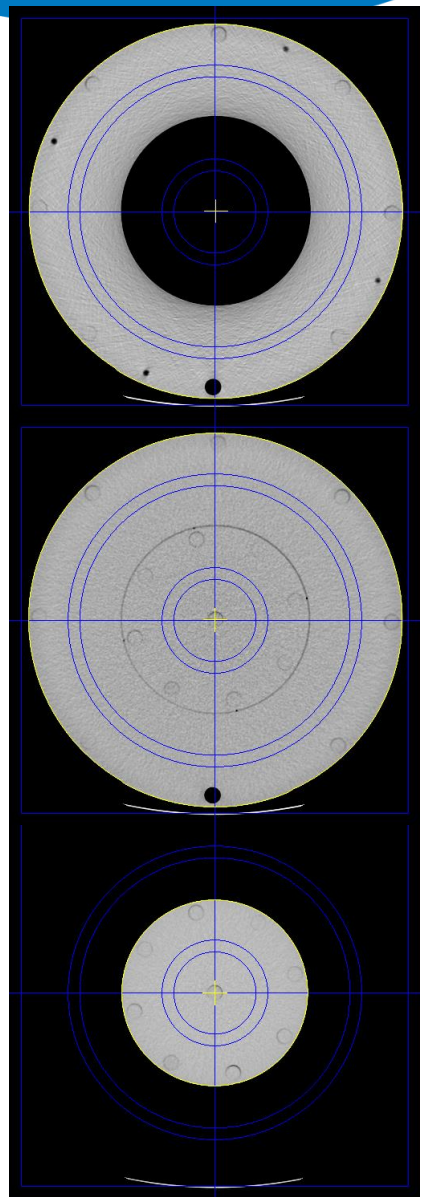
Testing Method: Image Analysis

- Simple IQWorks analysis tree
  - Position two annular ROIs in each image
    - One in head phantom
    - One in body annulus
  - Measure CT# and noise
  - Extract mA from each image

Annular ROIs

- At each end of phantom one of ROIs is in air not PMMA
- Spikes in noise at boundaries of sections
- Take noise from central 4cm of each section for global noise analysis





Systems tested

- Tested systems from all 4 CT manufacturers
  - GE: 9, Philips: 2, Siemens: 17, Toshiba: 1
  - 229 surveys where AEC test performed
  - 137 surveys where baselines not set/re-set
    - Baseline re-set for new tube/generator, change of protocol, other major maintenance as necessary

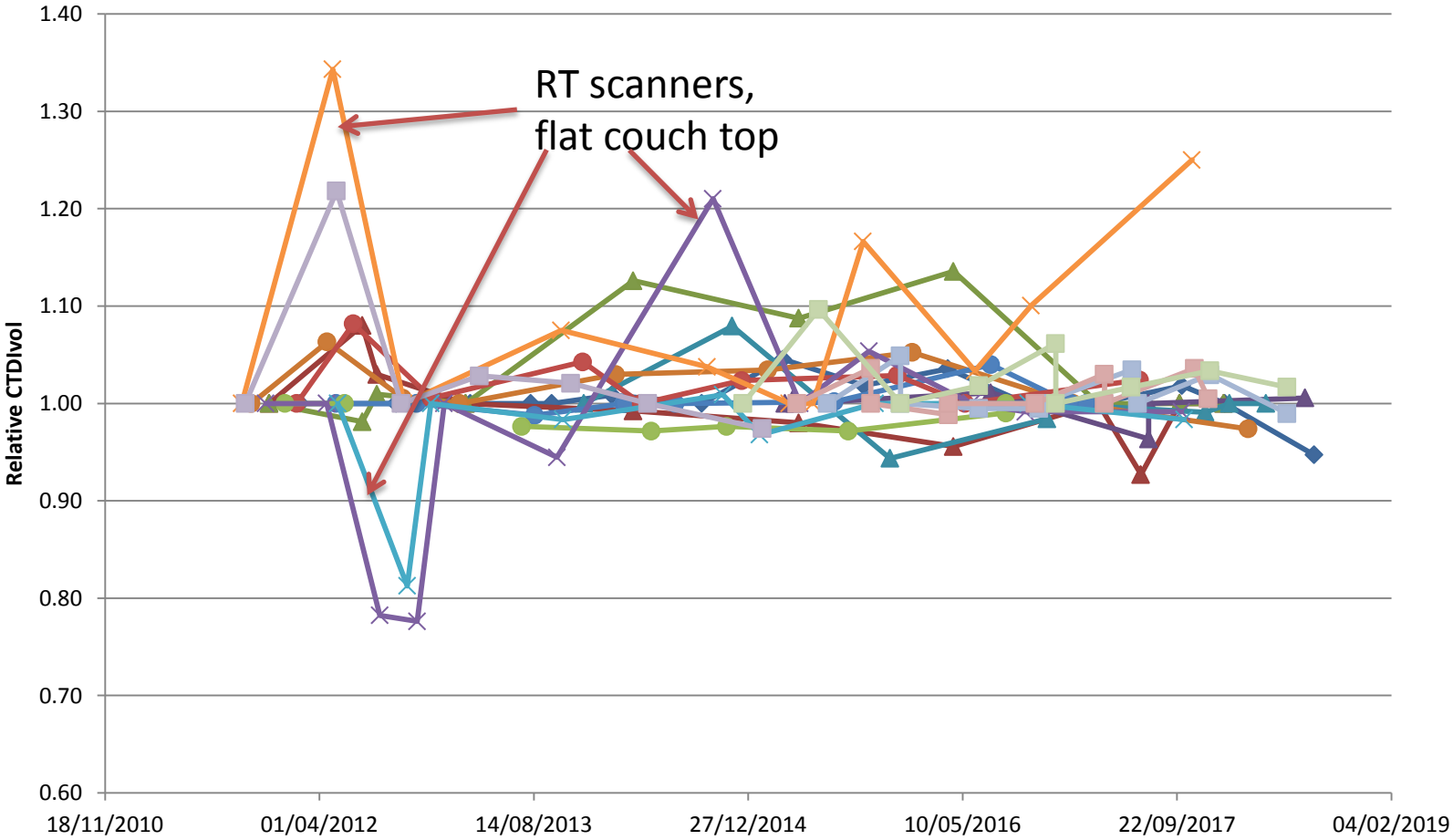
Systems with auto kV selection

- Seven scanners with auto kV software
  - 47 sets of AEC tests performed
  - Scanner selected kV never changed from baseline value

Results by manufacturer

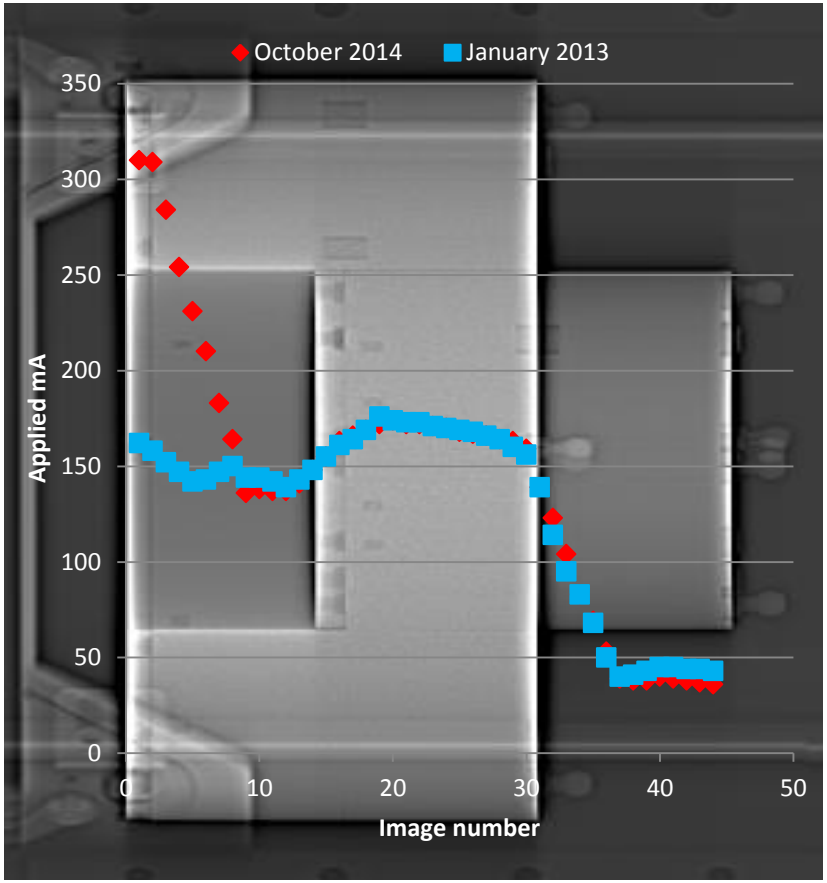
	Number of tests	CTDIvol >5%	CTDIvol >10%	CTDIvol >15%	Noise >2%	Noise >5%	Noise >10%
GE	51	28	12	8	60	24	12
Philips	11	63.6	54.5	27	54.5	54.5	9.1
Siemens	157	21.4	10.2	6.1	25.5	11.2	2
Toshiba	10	40	30	20	20	20	0
Total	229	28.5	16.1	9.5	35.0	18.2	4.4

Siemens scanners

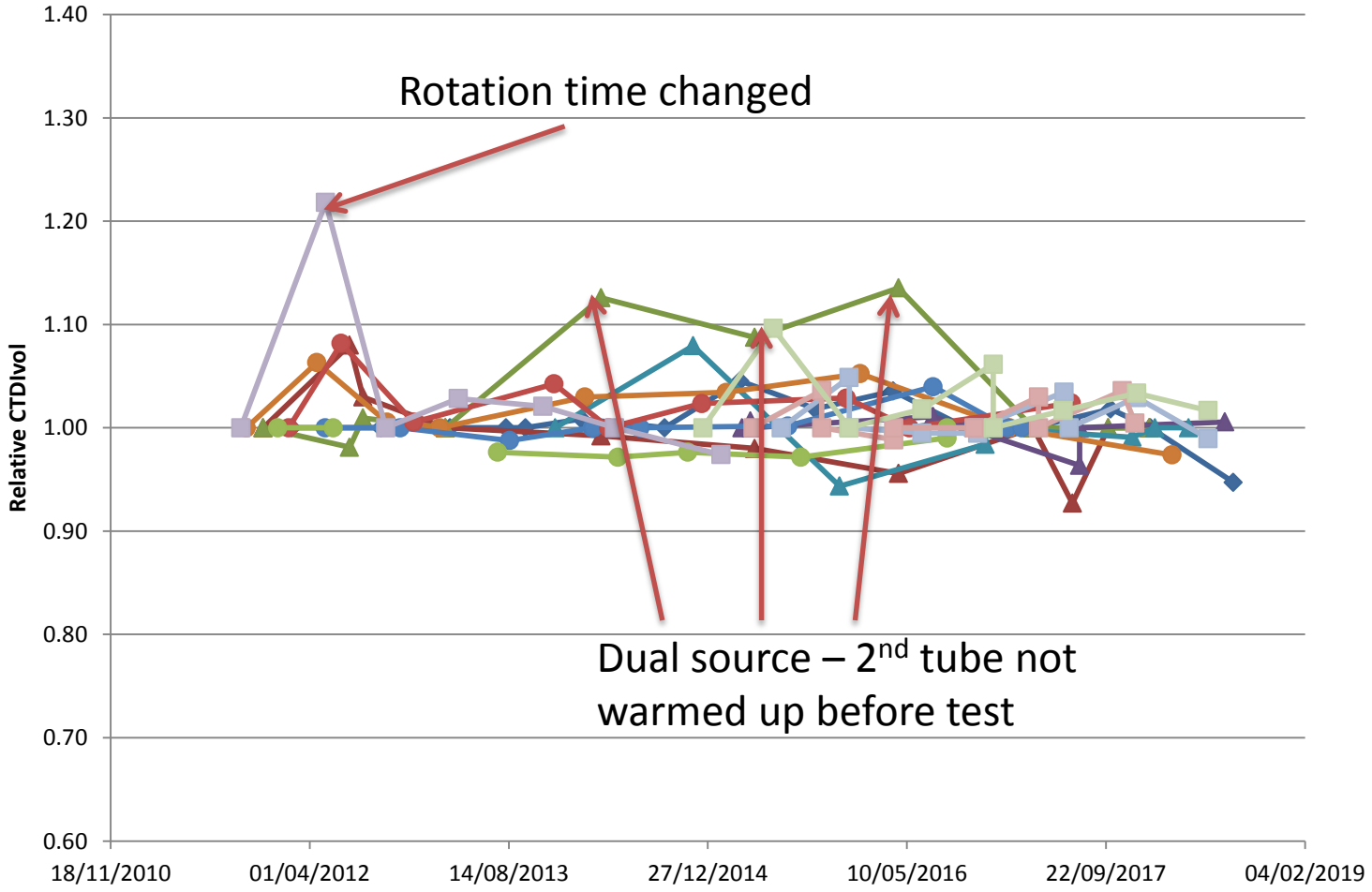


Radiotherapy couch top issues

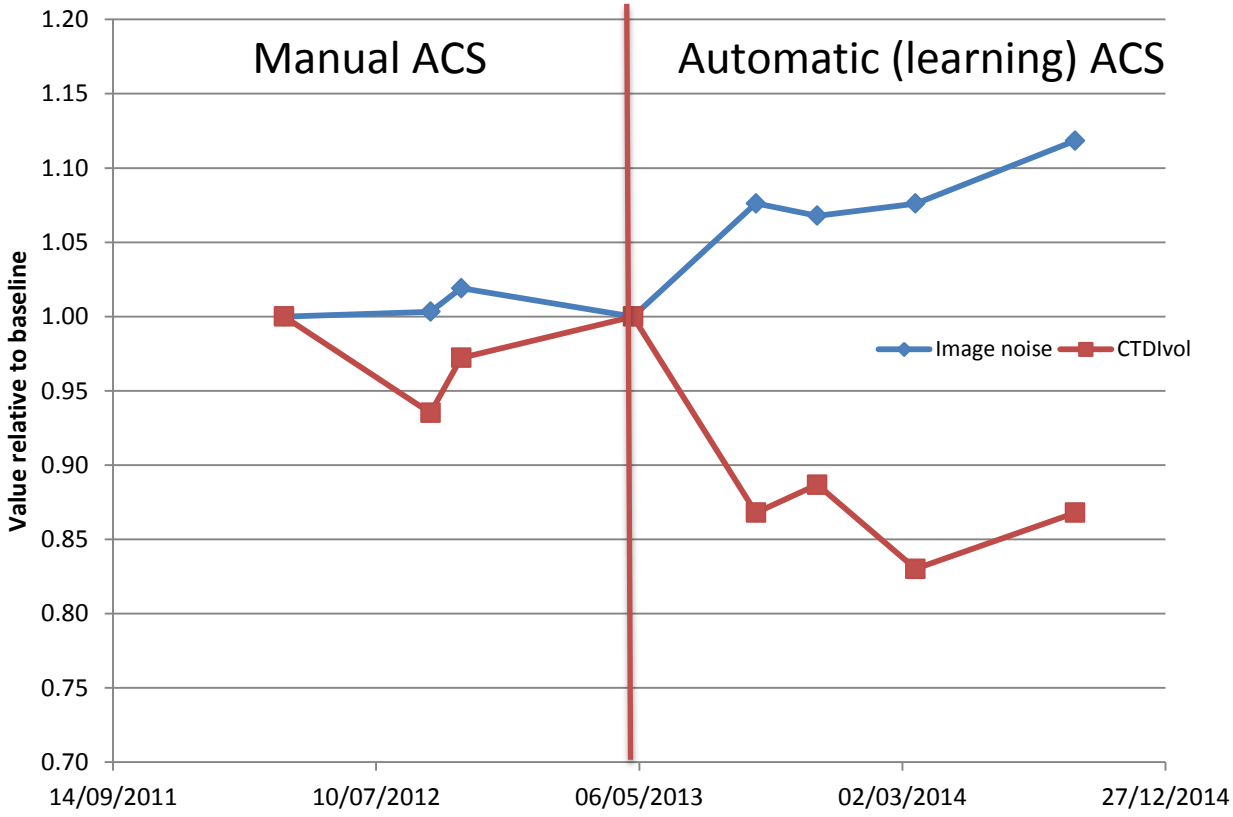
- iBeam Evo couch top has denser area at join of main section and head extender
  - RT treatments avoid this area
  - Causes notable mA increases
    - Cause of most “failures” on our CT Simulators
    - These falsely distort the failure rates



Siemens without RT systems



Philips scanners



Toshiba scanner

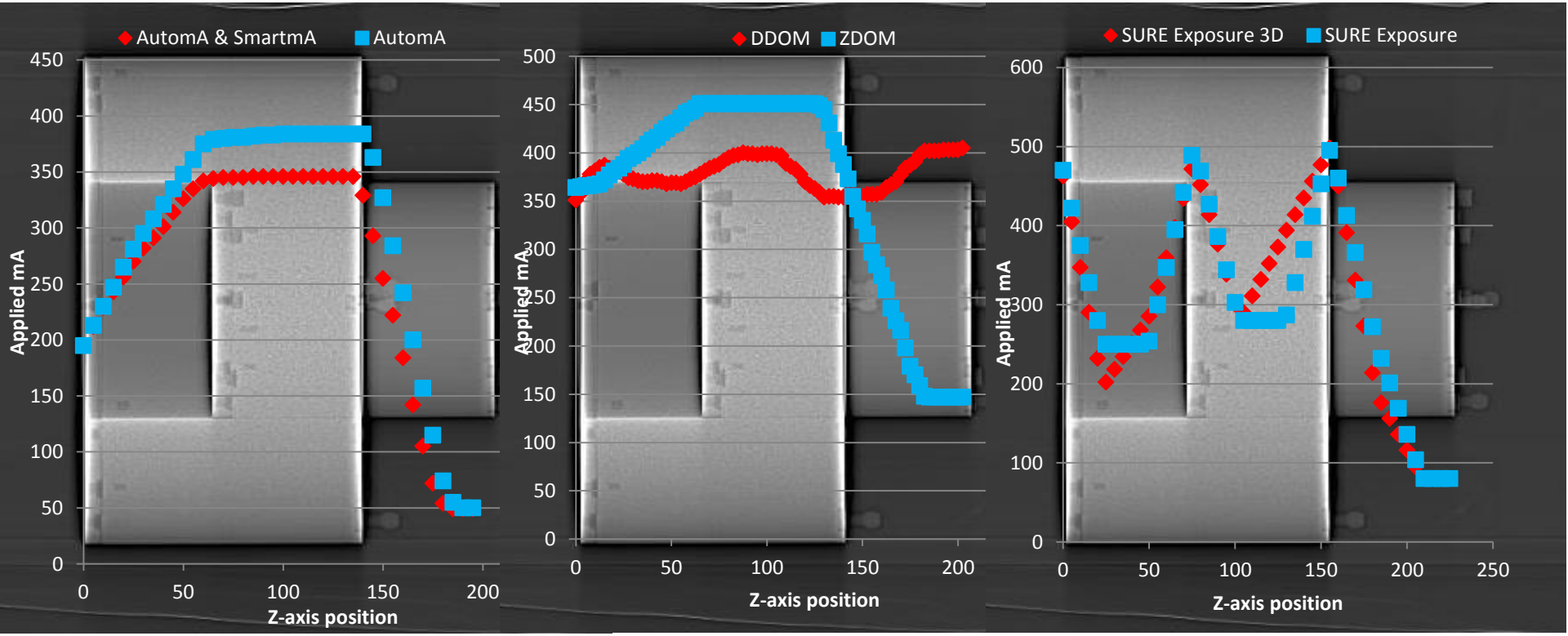
Revised results when obvious errors removed

	Number of tests	CTDIvol >5%	CTDIvol >10%	CTDIvol >15%	Noise >2%	Noise >5%	Noise >10%
Original data	229	28.5	16.1	9.5	35.0	18.2	4.4
Errors removed	211	20.5	8.2	4.9	31.1	16.4	4.1

Tolerances for AEC test

- Dosimetry:
  - >15% change in average mA, CTDIvol or DLP
  - Notable change in mA profile
- Image noise:
  - >10% change in global image noise
  - Notable change in noise profile

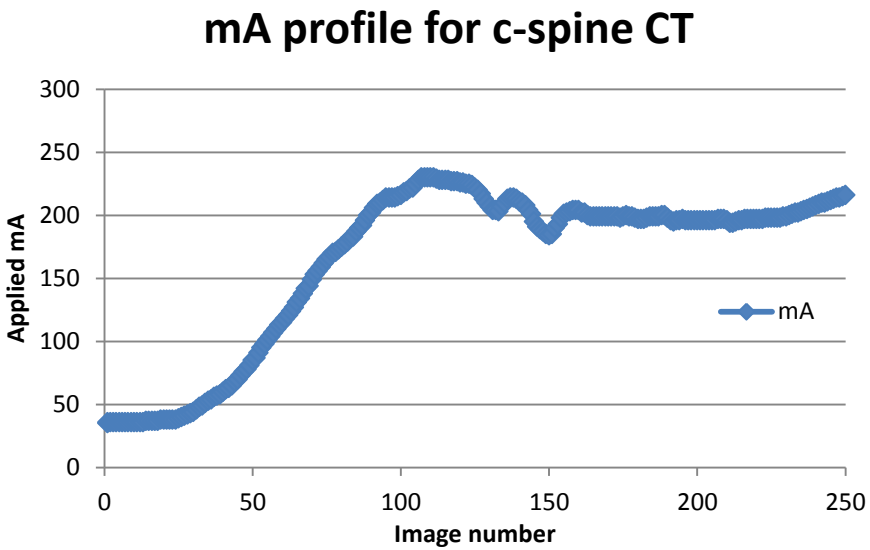
Phantom issues – non-elliptical



- Demonstrates phantom (and couch) presents rotational variations in attenuation which are detected and accounted for by AEC systems

Phantom issues – step change in mA too great

- Typically observe factor of 3 to 8 variation in mA between head and body sections
- Frequently observe similar mA variations in c-spine CT over ~10cm scan length
- mA variations in phantom well matched to scan type where AEC use is very beneficial



Potential phantom issues?

- It is not elliptical
  - Does provide rotational variations in attenuation due to helical scan and presence of couch
- It is uniform PMMA
  - Haven’t seen AEC system change selected kV
  - PMMA construction fine for routine QA
- It has large step changes in attenuation
  - Not different from mA profiles observed clinically

What have we learned?

- Robust testing of AEC is straightforward
- A simple phantom can be used
  - Sensitive to x-y-z mA modulation
- Dedicated Physics scan protocol is needed
- Take care over phantom set up/scan technique
  - Position in gantry, scan length, scan direction
- Reproducible results are possible
- Manufacturers don’t know what to do if tolerance is exceeded


JUST DO IT.