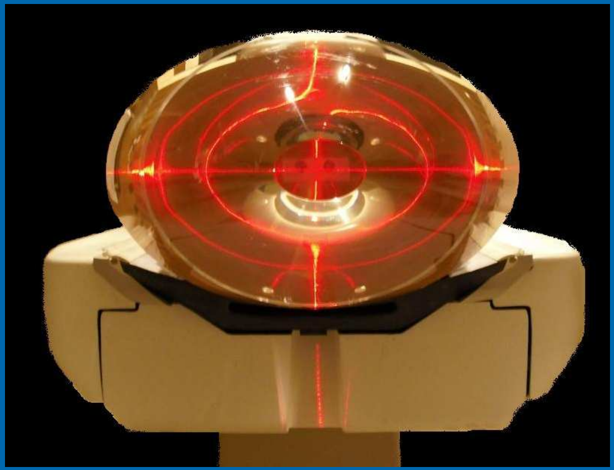
Comparison of the function and performance of CT AEC systems



CTUG meeting

by

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14th October 2010

Breakdown

- CT Automatic Exposure Control (AEC) Background
- Project Description
  - Aim
  - Methodology
  - Results
  - Conclusion

AEC systems in CT

What is the aim of AEC in CT?

- To minimise or remove variations in image quality between different images.
- To reduce variation in doses delivered to patients of varying sizes/shapes.

How is this achieved?

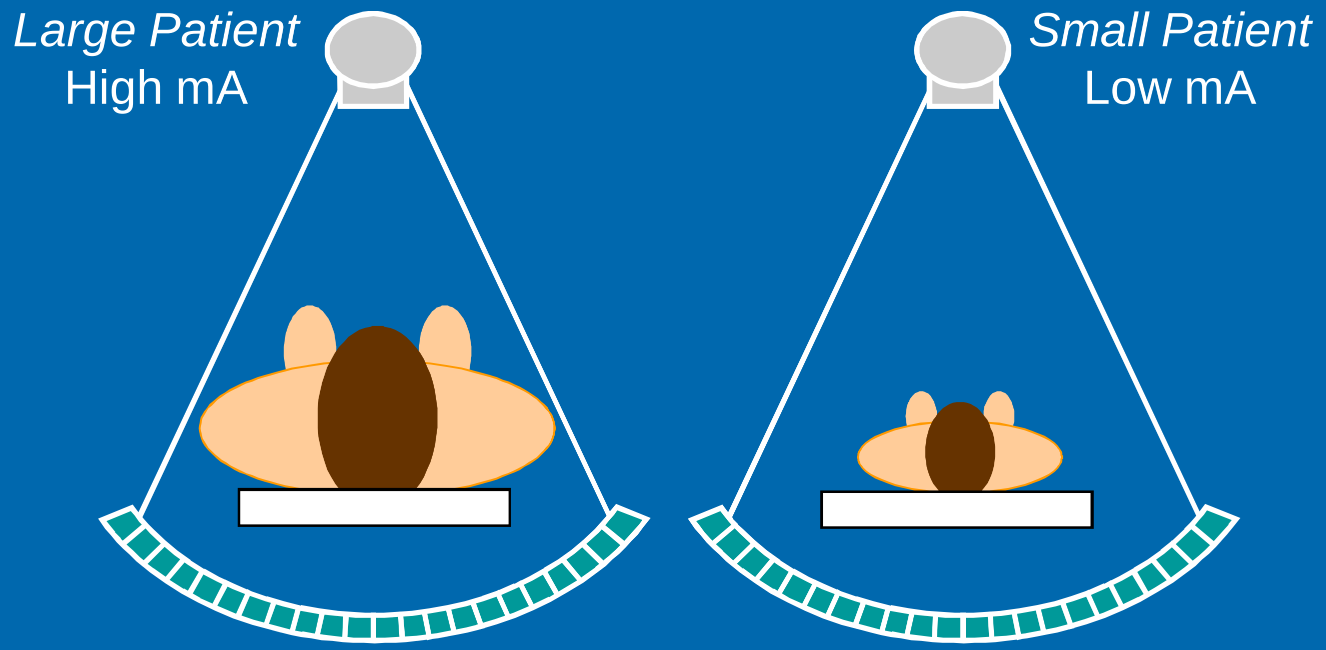
- This is made possible in CT scanning by controlling the tube current (mA) during scanning to achieve the required level of image noise. This is also known as *mA modulation.*

Modern CT scanners can achieve mA modulation in 3 distinct ways………

AEC systems in CT

1. Patient size AEC

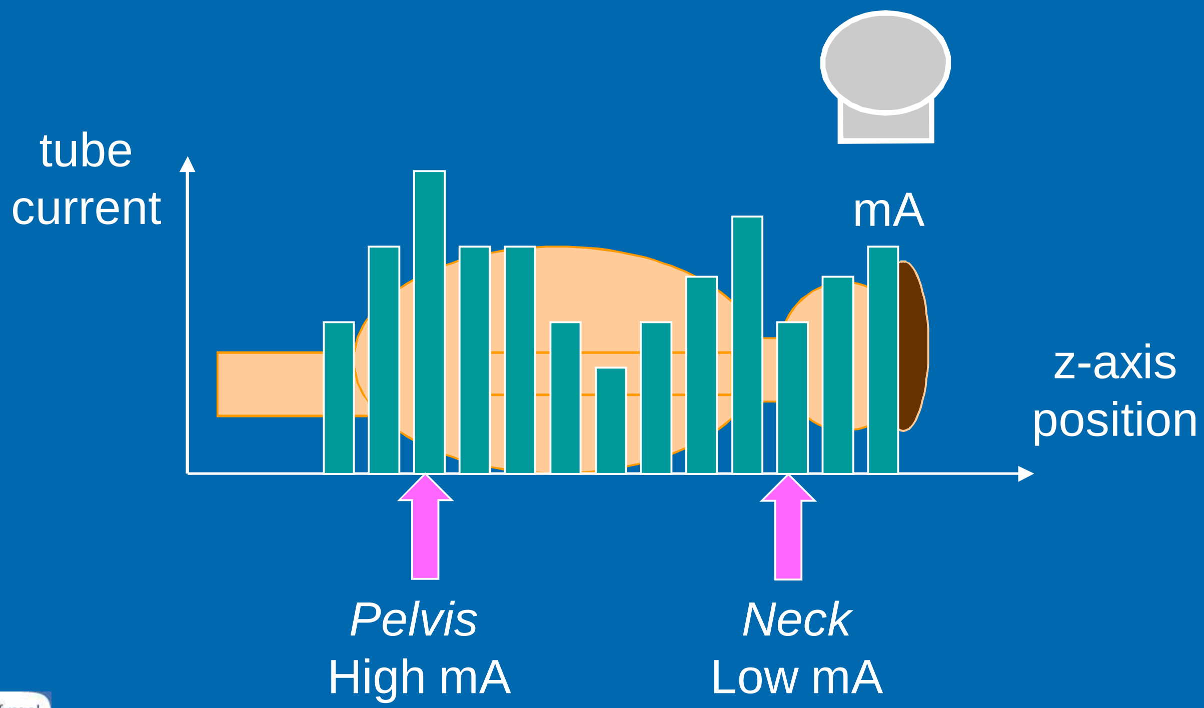
- mA is adjusted grossly based upon the overall size of the patient.



AEC systems in CT

2. Z-axis AEC

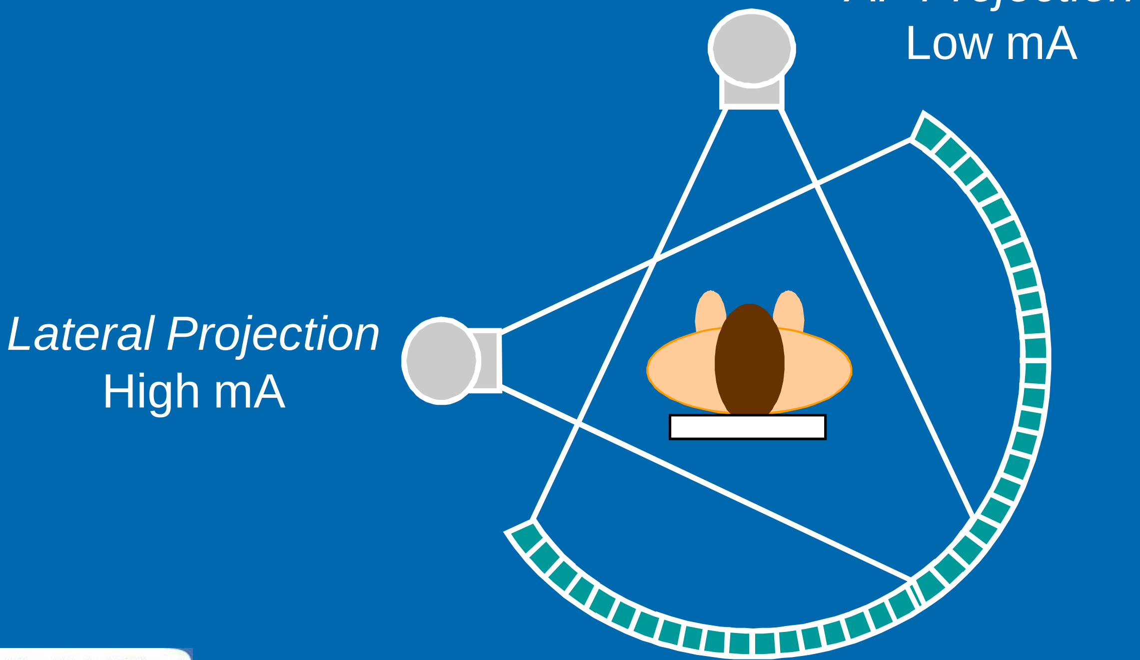
- Variations in attenuation along the length of the patient are compensated for by adjusting the mA for each successive tube rotation.



AEC systems in CT

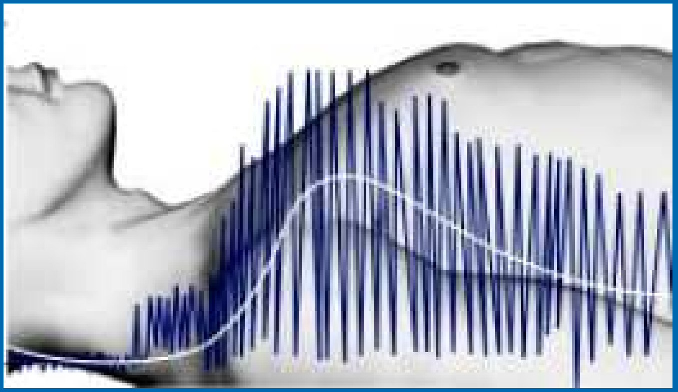
3. Rotational AEC

- mA is adjusted during a single rotation of the tube to compensate for differences in attenuation between AP and Lateral projections.



AEC systems in CT

- In reality, **all three** AEC systems operate simultaneously.



Patient and z-axis AEC

- The main source of patient attenuation data necessary for operation of the AEC system is acquired during the *scan projection radiographs* (SPRs). These are also known as scouts, topograms or scanograms.

Rotational (x, y – axis) AEC

- Feedback - changes in patient profile occur gradually along the z-axis, many systems utilise real-time feedback to inform the system of the changes in attenuation. For example, the patient attenuation data acquired during a single rotation can be used to inform the system of the optimum mA settings for the subsequent rotation.
- SPR - asymmetry of the patient can be estimated from SPRs and the x-ray tube current varied accordingly.

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AEC systems in CT - Benefits

What are the overall benefits?

- Consistent image quality - User defined levels of image noise achievable from slice to slice but also from patient to patient.
- Potential to reduce patient exposure - A fully optimised CT system can avoid unnecessary exposure of the patient.
- Reduced tube loading - Modulated mA runs have the potential to reduce the overall loading of the x-ray tube.
- Extended scan runs - A reduction in x-ray tube heating means that longer scan runs can be utilised where necessary.
- Reduction of photon starvation artefacts - Rotational AEC means that previously under-sampled lateral projections (e.g. across shoulders) can be avoided.

AEC systems in CT

- Each major CT manufacturer has their own version of AEC.

Manufacturer	Patient size AEC	Z-axis AEC	Rotational AEC	Method for setting exposure level
GE	AutomA	AutomA	SmartmA	"Noise Index"
Siemens	Care Dose 4D	Care Dose 4D	Care Dose 4D	"Reference mAs"
Toshiba	Sure Exposure	Sure Exposure	Sure Exposure 3D	Standard deviation
Philips	DoseRight ACS	-	DoseRight DOM	"Reference image" noise level

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Study Aim

To assess the efficacy of a range of CT scanner AEC systems using a homogeneous elliptical cone phantom. Variations in performance characteristics between scanner models and manufacturers was also investigated.

Scanners Tested

Hospital Site	Scanner	Make/Model	Slice
A	CT1	Toshiba Aquilion	64
	CT2	Toshiba Aquilion	16
B	CT	Toshiba Aquilion	64
C	CT	Toshiba Aquilion	64
D	CT	Toshiba Aquilion	64
E	CT1	GE Discovery HD750 (dual kV) with ASIR	64
	CT2	GE Lightspeed	16
	CT3	GE Lightspeed	64
F	CT	GE Lightspeed with (ASIR)	8
G	CT	GE Lightspeed	64
H	CT	Siemens Sensation	64

Methodology – The Phantom

- Homogeneous, acrylic, elliptical, cone-shaped phantom.
- Same phantom used by ImPACT for their 2005 report[1] (Thank you!).
- Designed to test each distinct AEC system (z-axis, rotational etc…)

Phantom dimensions (30cm z-axis length).

[1] *CT scanner automatic exposure control systems.* Medicines and Healthcare Regulatory Agency, February 2005. Report 05016

Methodology – Standard Settings

- Standardised test protocol for every CT scanner attempted for fair comparison (*120kVp, 1sec rot time, standard reconstruction parameters, 5mm slice recon, large FOV*).
- However, slight variations unavoidable between models/manufacturers (below).

Manufacturer	Detector Rows	Collimation (mm)	Helical /Axial	Pitch	AEC system	Image quality settings
GE	64	2x5	Axial	-	AutomA, SmartmA	NI 10, 10-750mA
	16	8x1.25	Axial	-	AutomA, SmartmA	NI 10, 10-750mA
	8	8x1.25	Axial	-	Auto mA	NI 10, 10-440mA
Siemens	64	64x0.6	Helical	0.6	CARE Dose 4D	Average, 210 quality ref
Toshiba	64	16x0.5	Helical	0.938	SureExposure4D	SD 10, 10-380mA
	16	16x0.5	Helical	0.938	SureExposure4D	SD 7.5, 80-410mA

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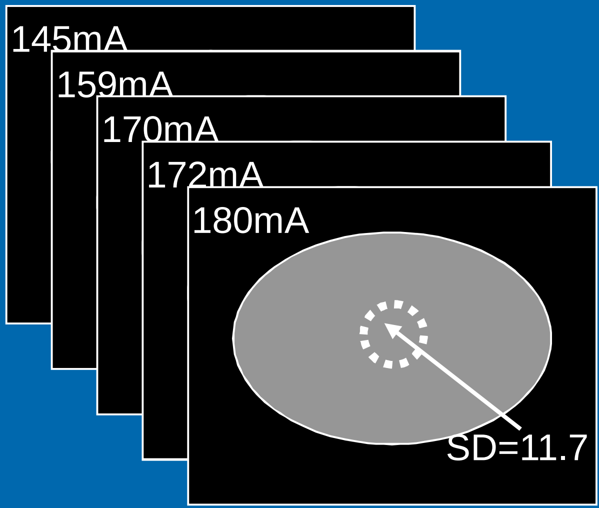
Methodology

- Scan projection radiographs (SPRs) acquired (AP and lateral) along entire phantom length.
- Scans of complete phantom length planned and performed from SPR images (based on previously described standard settings).
- Resulting sequence of images analysed in terms of two key parameters;

  1. Delivered mA for each slice (related to absorbed dose)
  2. Standard deviation of CT numbers in central ROI (measure of noise)

- The effect of adjusting several parameters on applied x-ray tube current and image standard deviation (noise level) were recorded;
  - kV
  - Pitch
  - Reconstruction kernel
  - AEC image quality setting e.g. noise index



Results

The following results are for 64-slice scanners only

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AEC on/off

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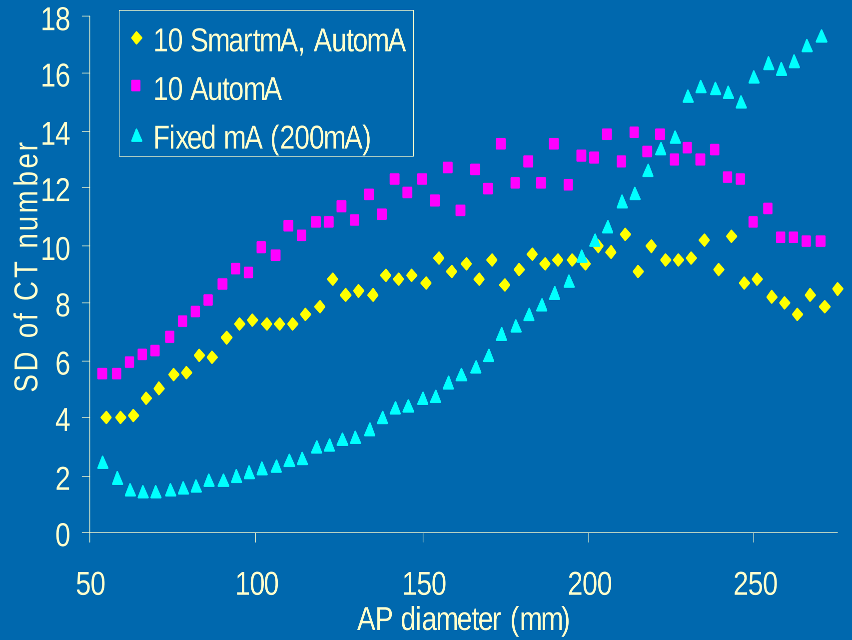
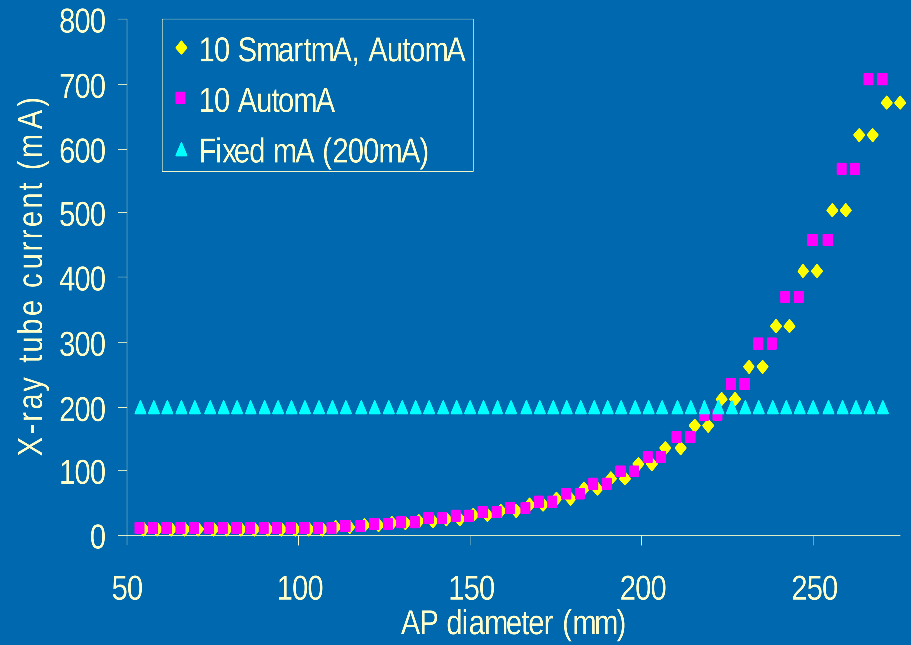
Results - GE





- AEC system maintains image quality as the AP diameter is increased.
- Image quality is improved when AutomA is combined with SmartmA

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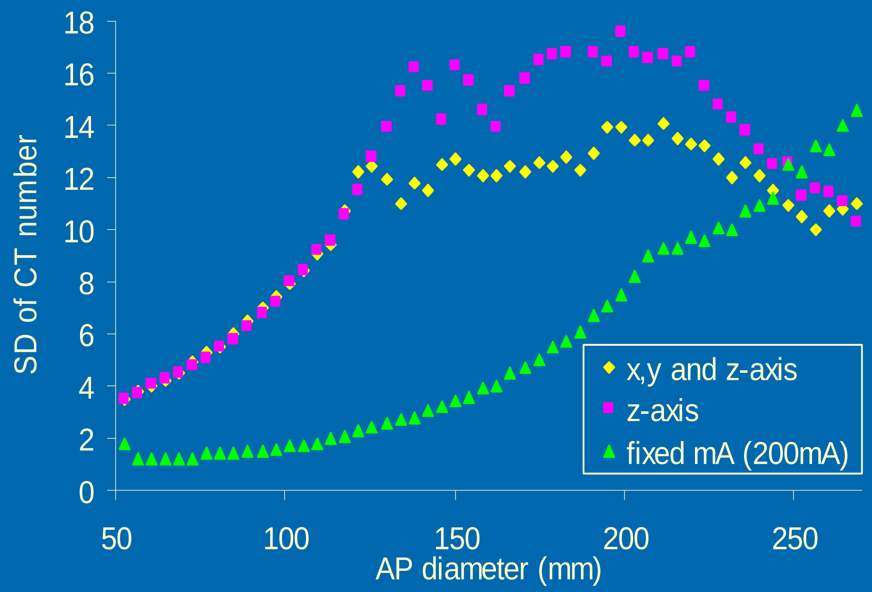
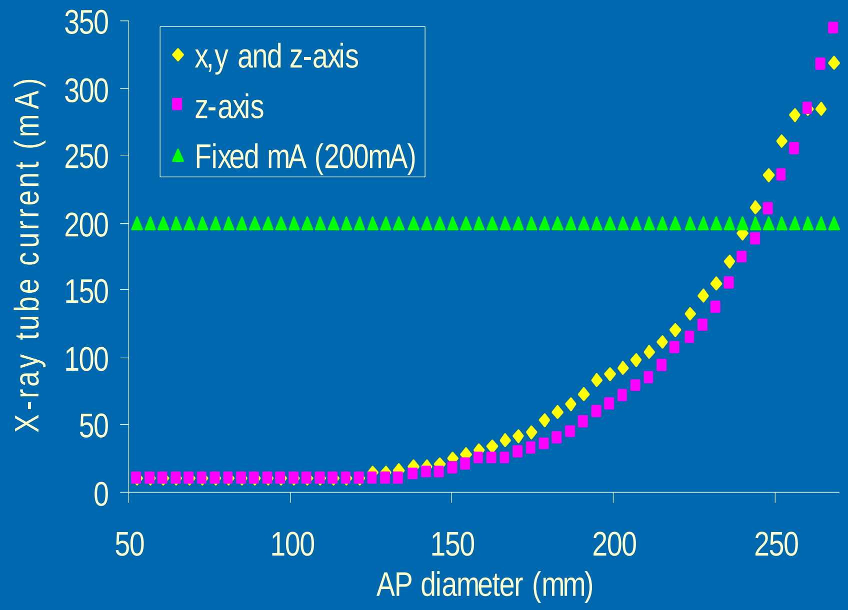
Results - Toshiba





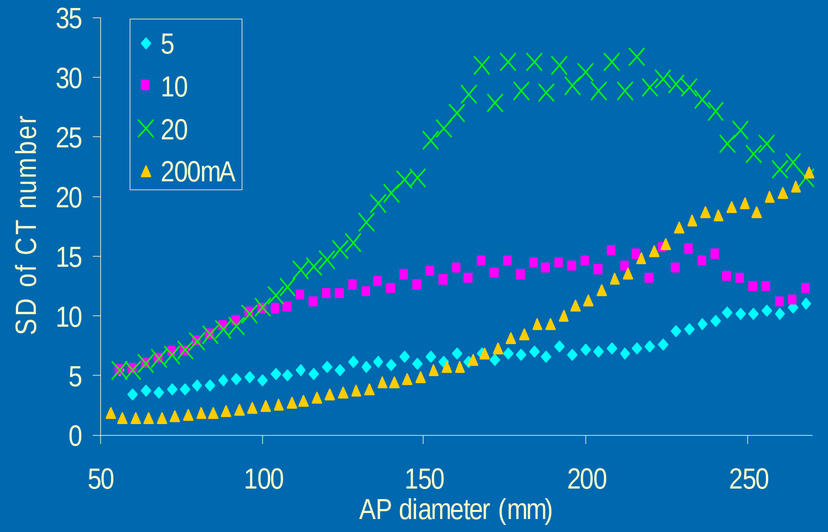
- AEC system maintains image quality as the AP diameter is increased.
- Image quality is improved when z-axis AEC is combined with x, y-axis AEC.

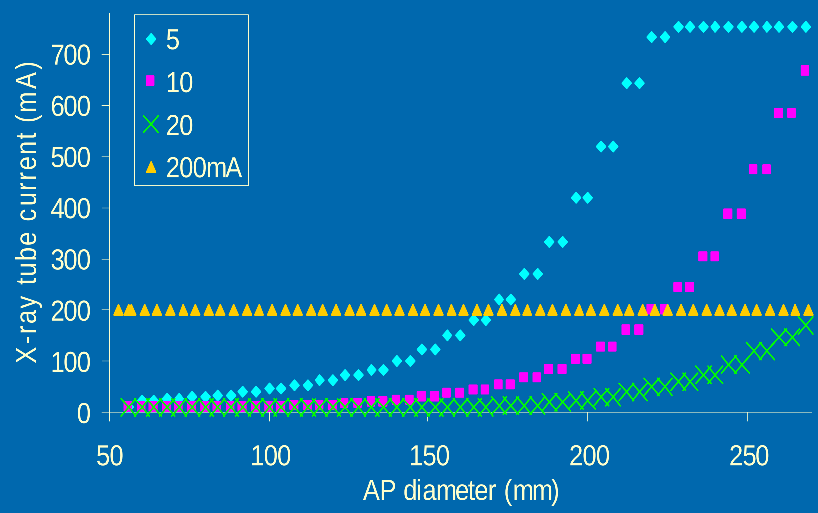
Results - Siemens

- Siemens z-axis and x, y-axis AEC system CareDose4D could not be operated independently.
- CareDose4D could either be selected with both AEC systems working together or not at all.

Varying image quality

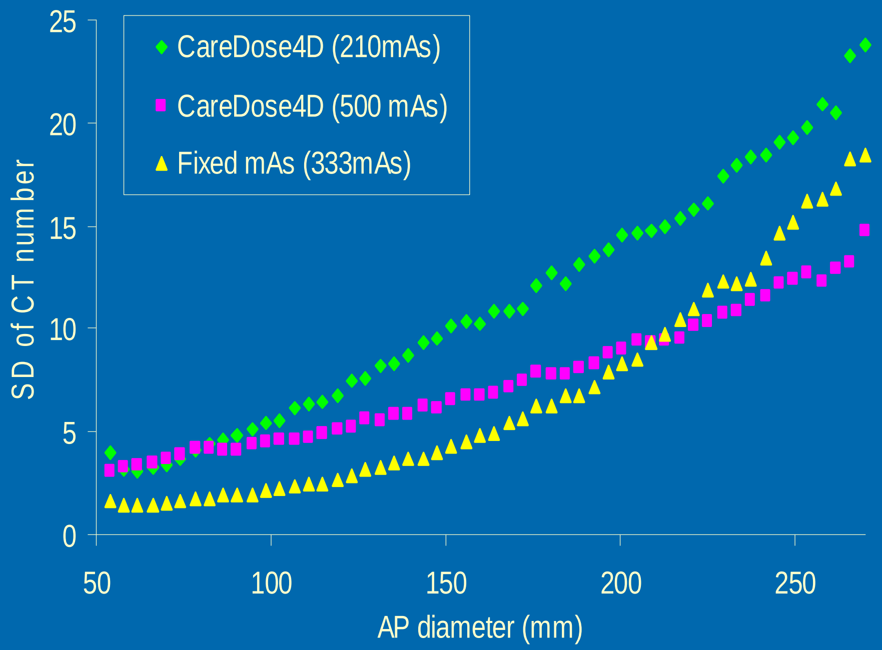
Results - GE

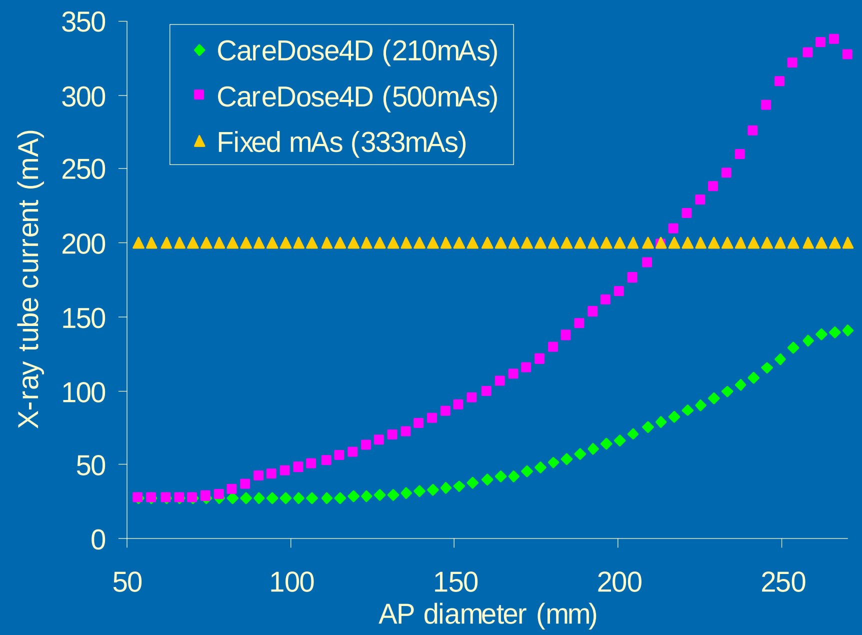




- Increasing image quality increases mA.
- Image quality is maintained at the required level more accurately at lower NI values.

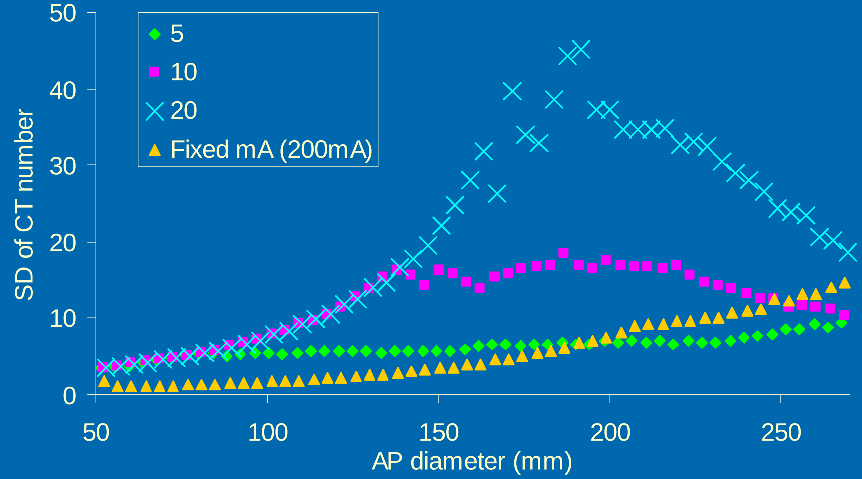
Results - Siemens

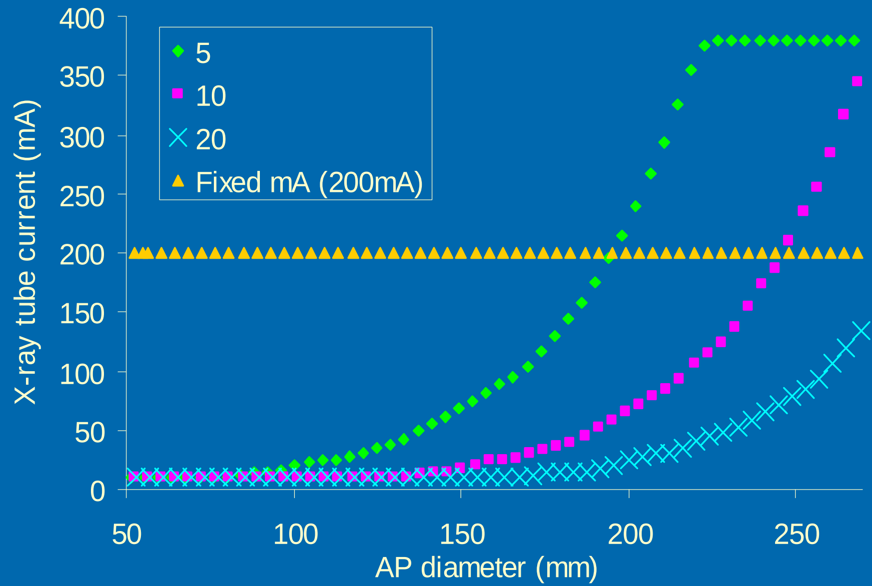




- Increasing the quality reference mAs increases the mA modulation.
- Image noise reduced for smaller AP diameters than larger ones. Therefore reducing the image noise for smaller patients and increasing it for larger ones (where it is more tolerable).

Results - Toshiba





- AEC system behaves in a similar fashion to GE
- Increasing image quality increases mA.
- Image quality is maintained at the required level more accurately at lower SD values.
- Increasing SD increases the AP diameter at which mA begins to be modulated.

Varying tube voltage

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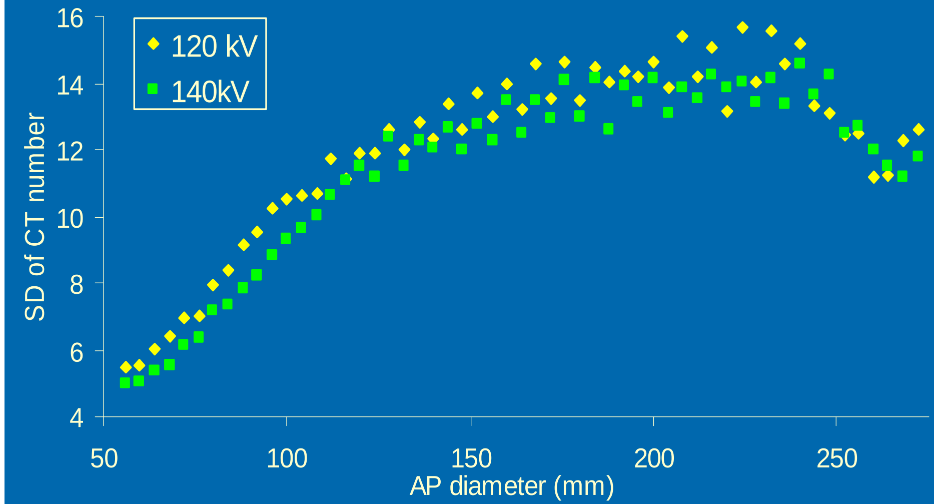
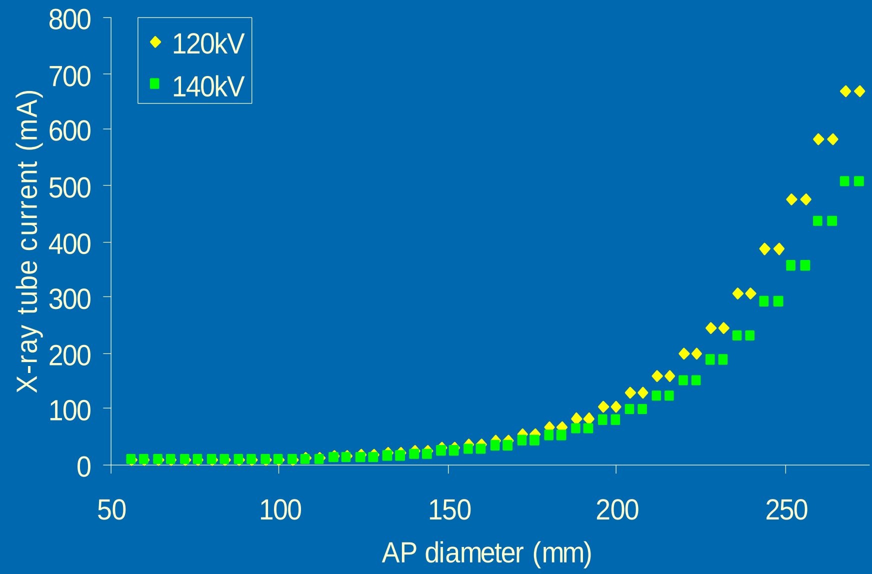
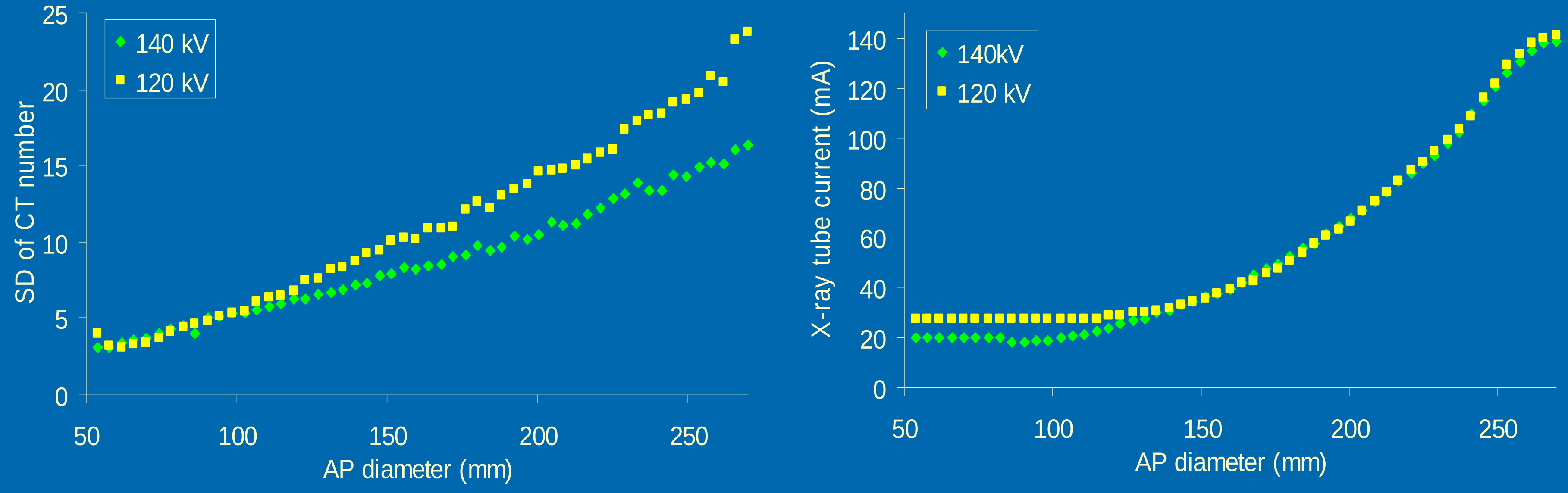
Results - GE





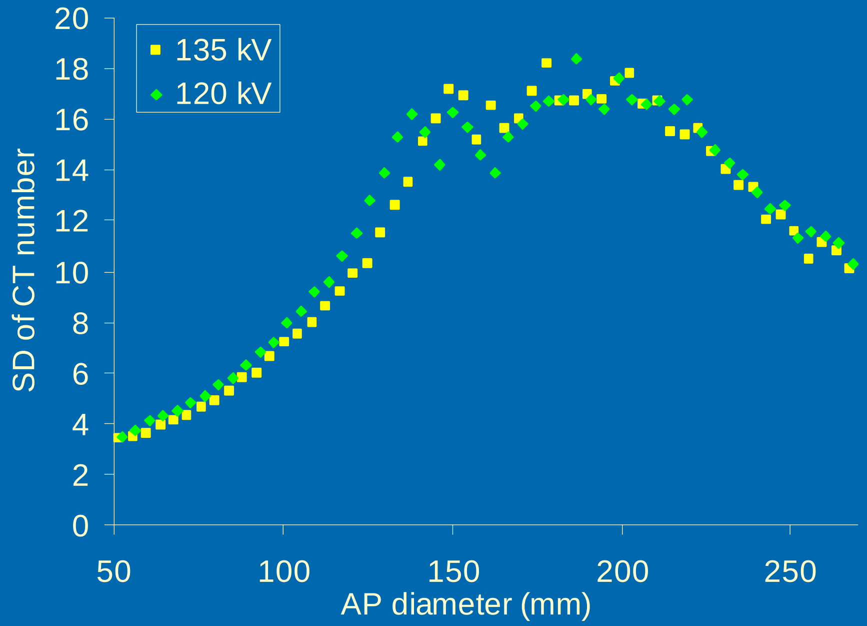
- Changing kV does not alter image quality.
- mA decreases when kV increases to maintain image quality.

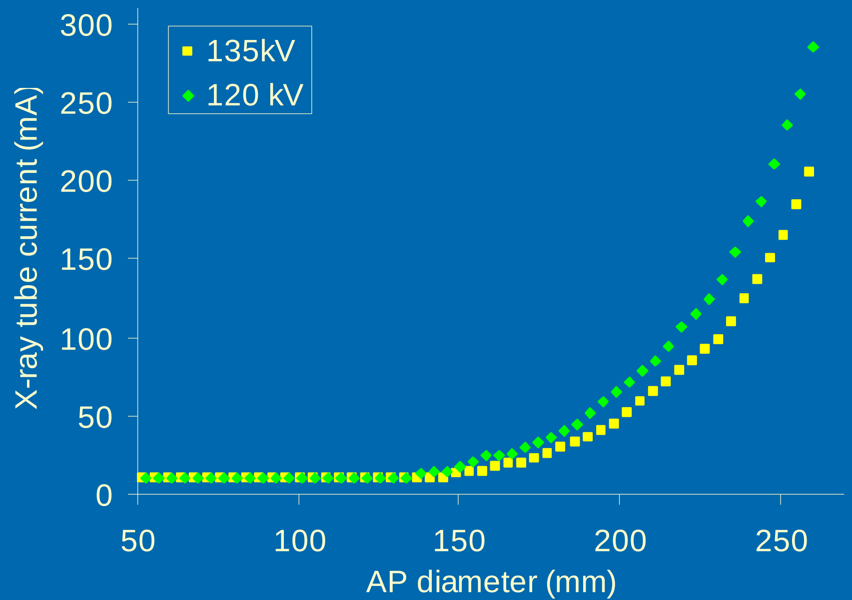
Results - Siemens



- Increasing kV increases the image quality, whilst mA remains constant at AP diameters greater than 130mm.

Results - Toshiba





- Changing kV does not alter image quality.
- mA decreases when kV increases to maintain image quality.

Varying reconstruction kernel

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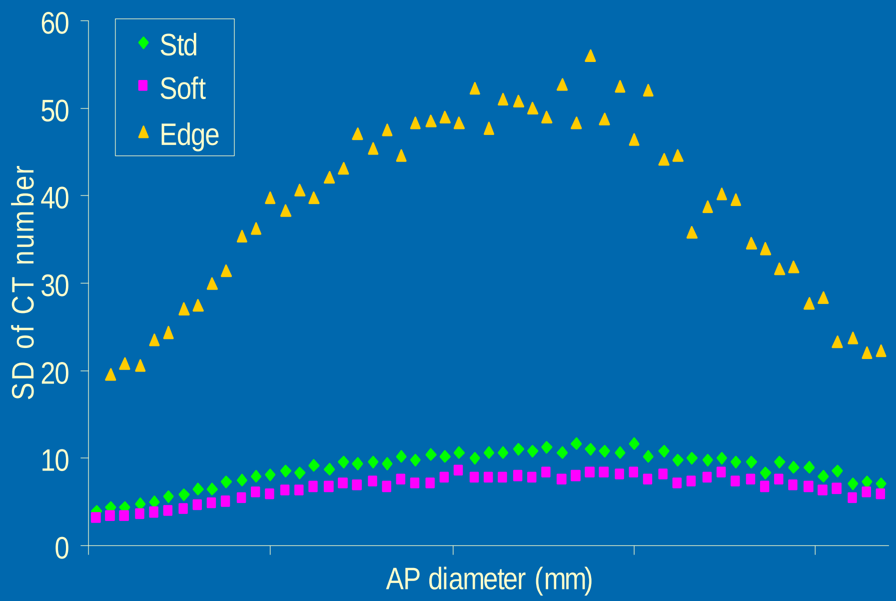
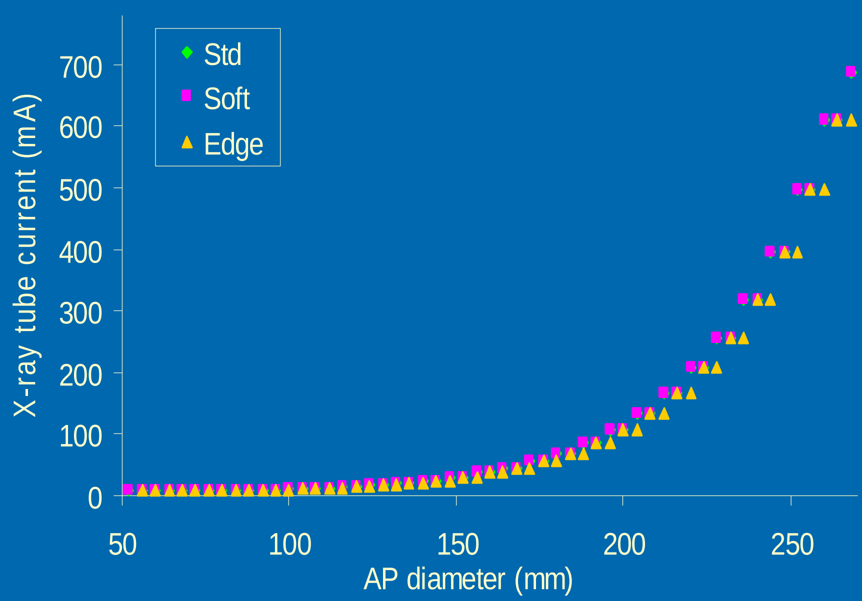
Results - GE





- Changing the reconstruction algorithm changes the variation in CT number for each pixel making up the image to alter the appearance.
- Reconstruction algorithm chosen did not alter the mA applied.

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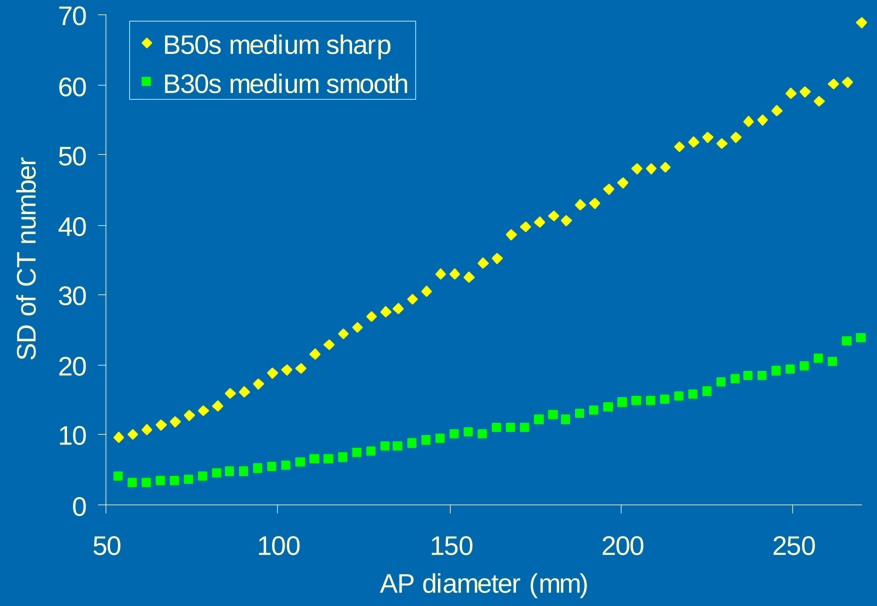
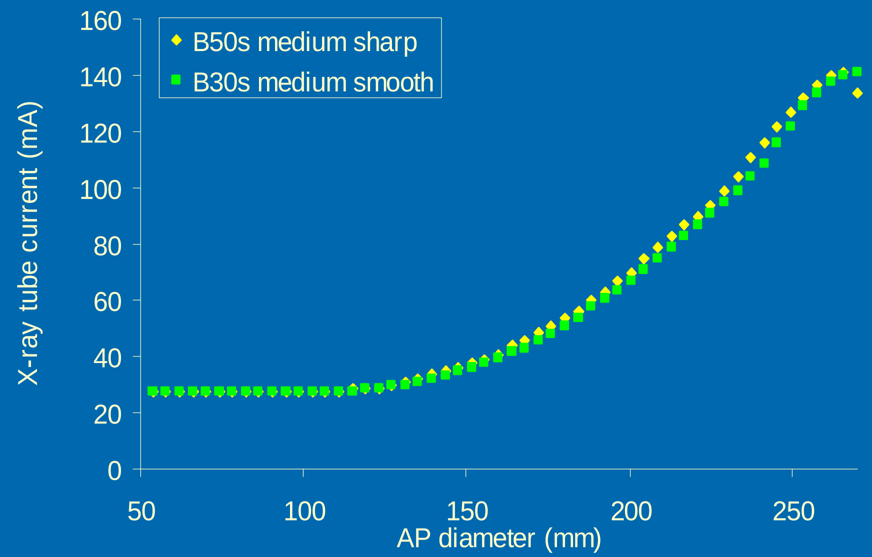
Results - Siemens





- Behaves similar to GE.
- Changing the reconstruction algorithm changes the variation in CT number for each pixel making up the image to alter the appearance.
- Reconstruction algorithm chosen did not alter the mA applied.

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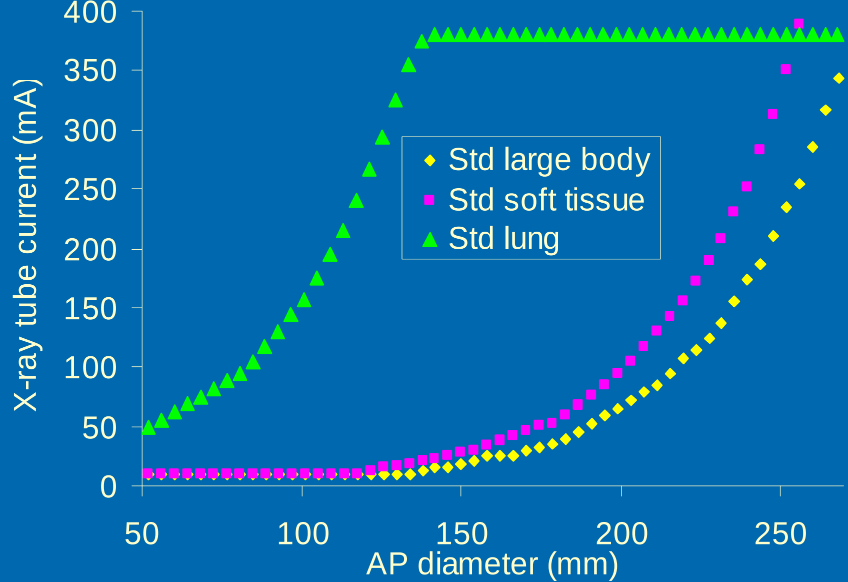
Results - Toshiba



- Changing the reconstruction algorithm changes the variation in CT number for each pixel making up the image to alter the appearance.
- Reconstruction algorithm chosen alters the mA applied along the phantom length.

Varying pitch

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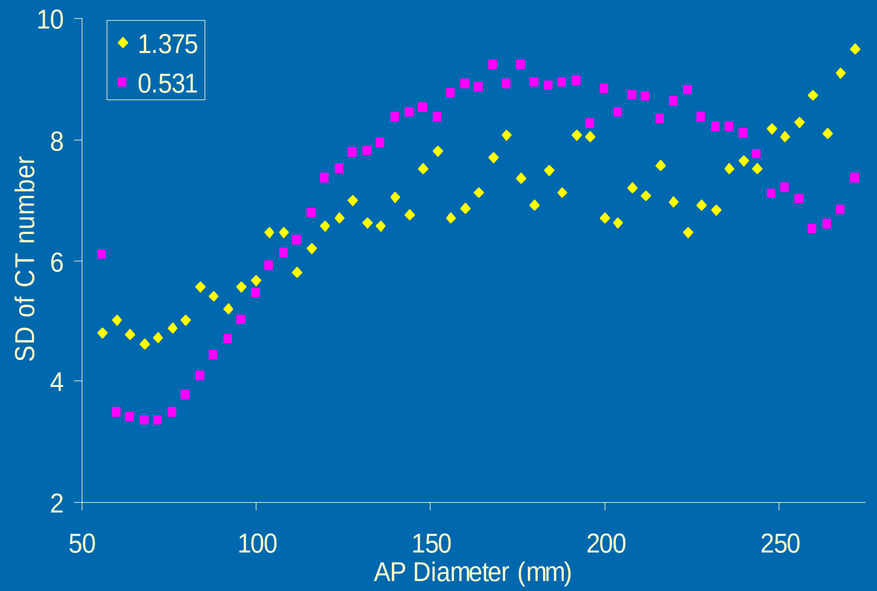
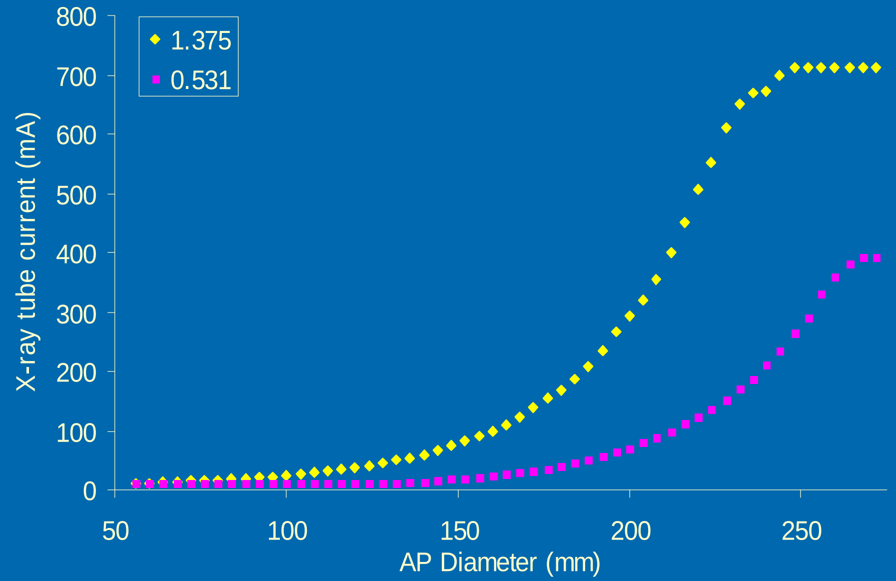
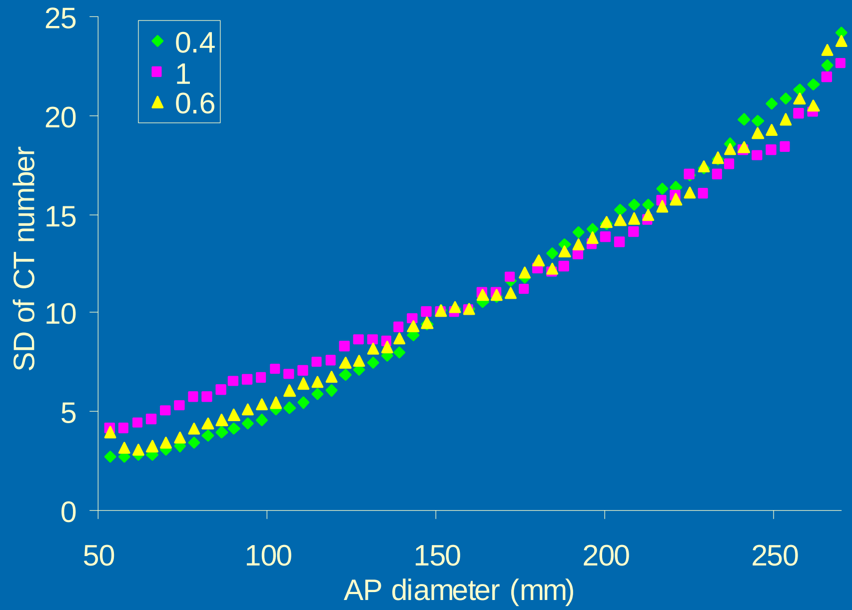
Results - GE

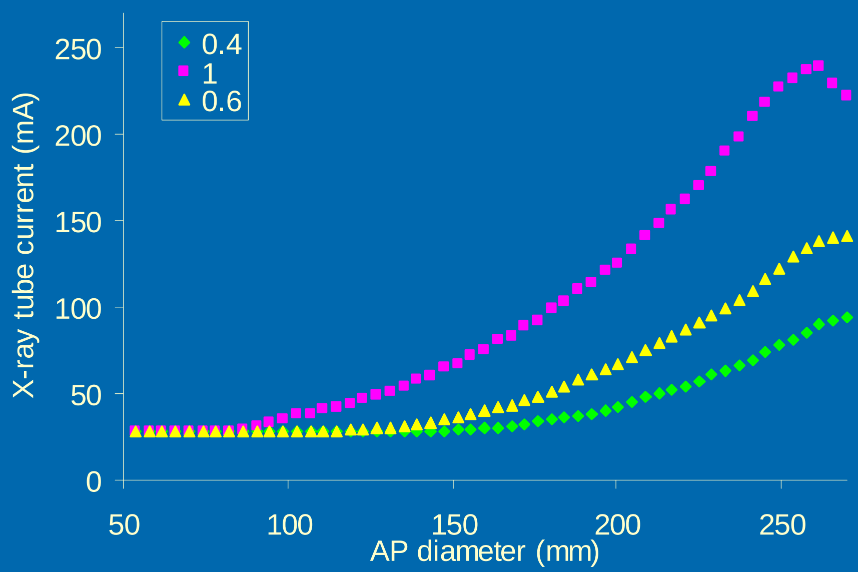




- Scan mode changed to helical with 40mm collimation to produce 5mm slices.
- Lowering pitch causes mA along the phantom to be reduced in order to achieve the NI specified.
- Reduced image noise between 100 and 250mm for increased pitch.

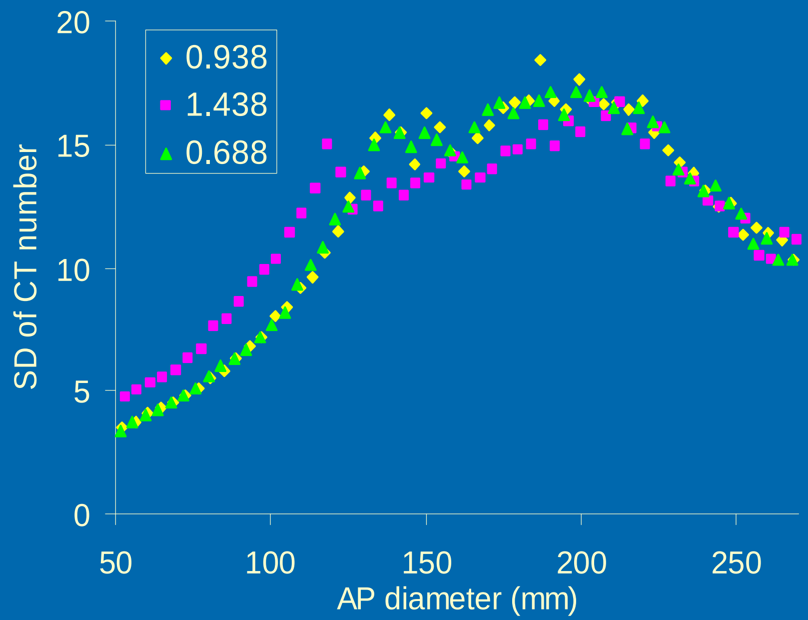
Results - Siemens

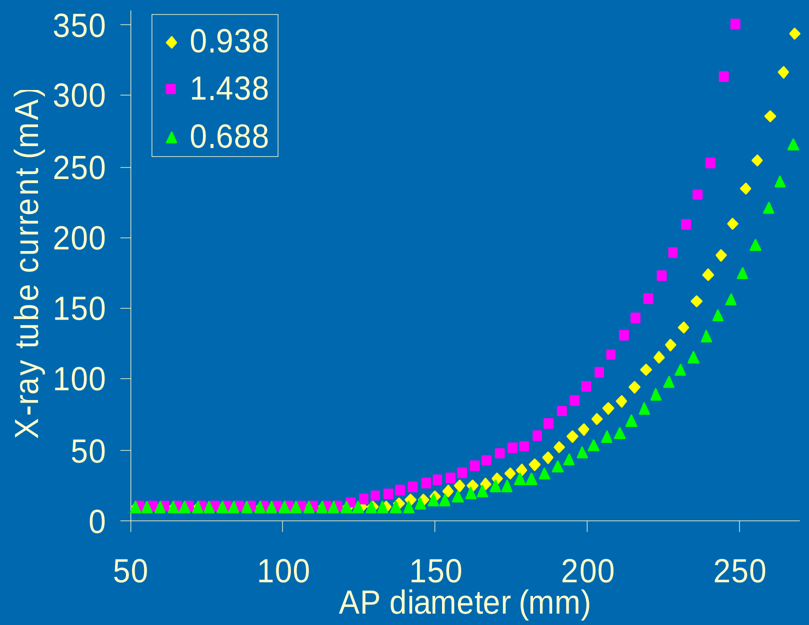




- Changing pitch has a similar effect on GE, Siemens and Toshiba 64 slice scanners.
- Lowering pitch causes mA along the phantom to be reduced in order to achieve the image quality specified.

Results - Toshiba





- Changing pitch has a similar effect on GE, Siemens and Toshiba 64 slice scanners.
- Lowering pitch causes mA along the phantom to be reduced in order to achieve the image quality specified.

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Intra-manufacturer variation

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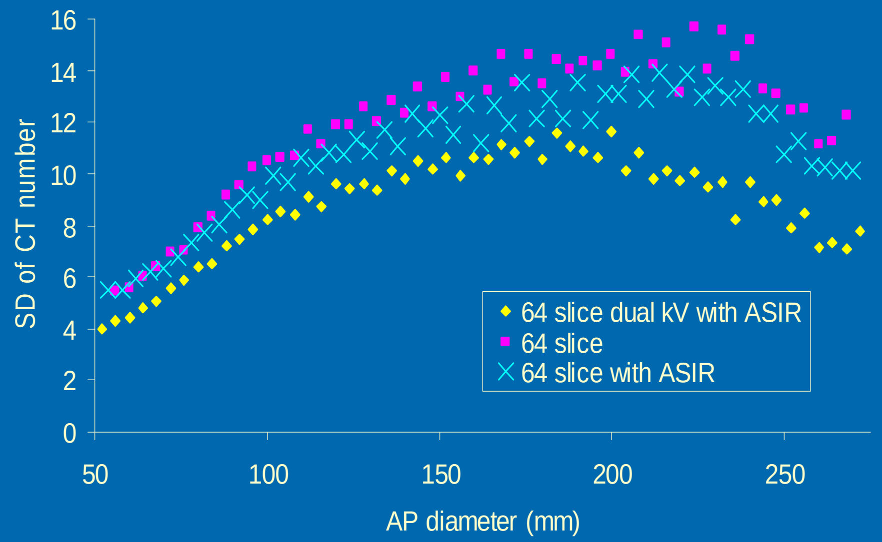
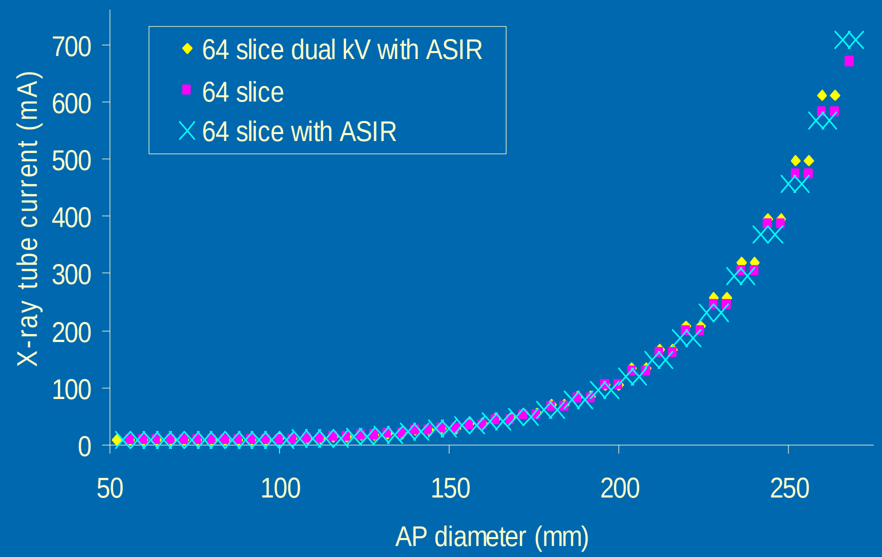
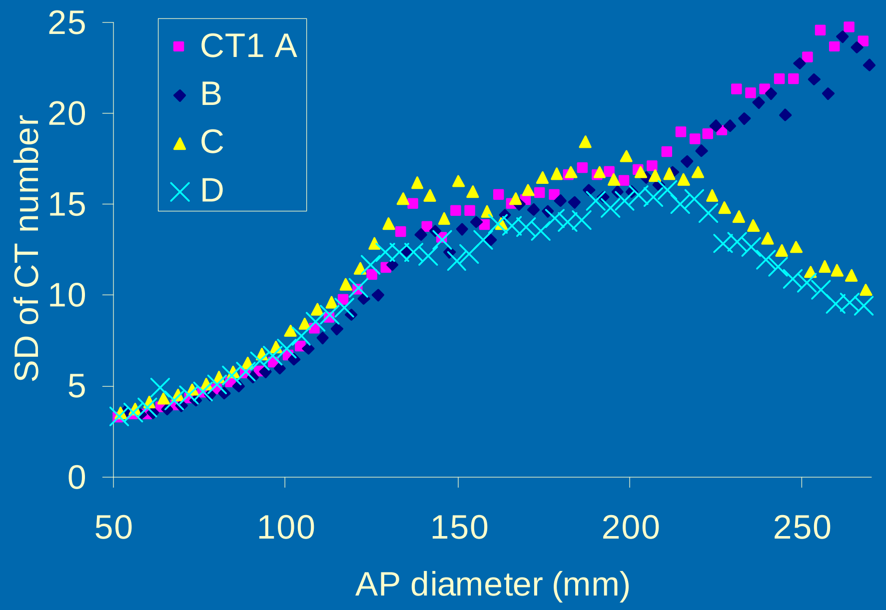
Results - GE

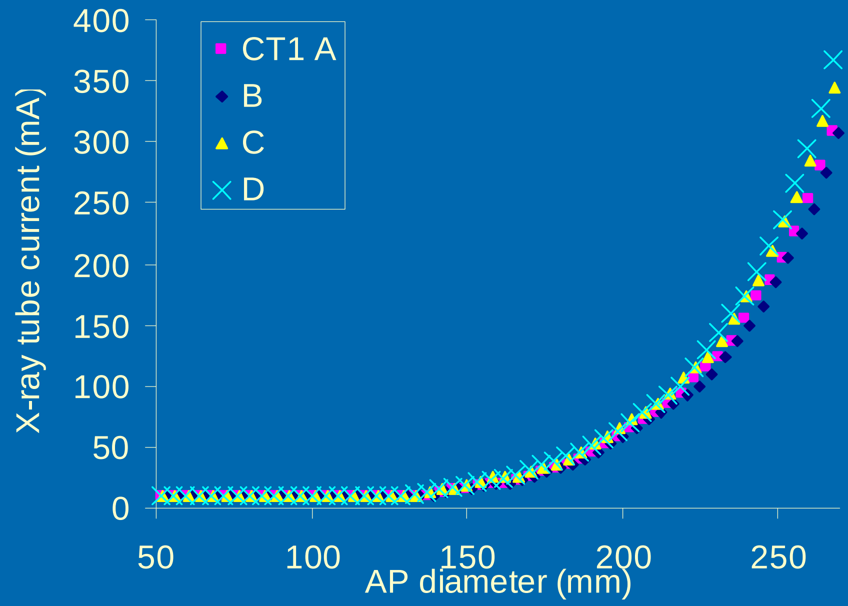




- Scanners with ASIR capabilities maintain image quality selected greater than the scanner without.
- The same mA modulation is apparent for the three scanners.

Results - Toshiba





- Comparison of AEC system performance of four 64 slice Toshiba Aquilions.
- CT1 A and B behave differently to C and D with the same settings applied.
- C and D maintain greater image quality at increased AP diameters.

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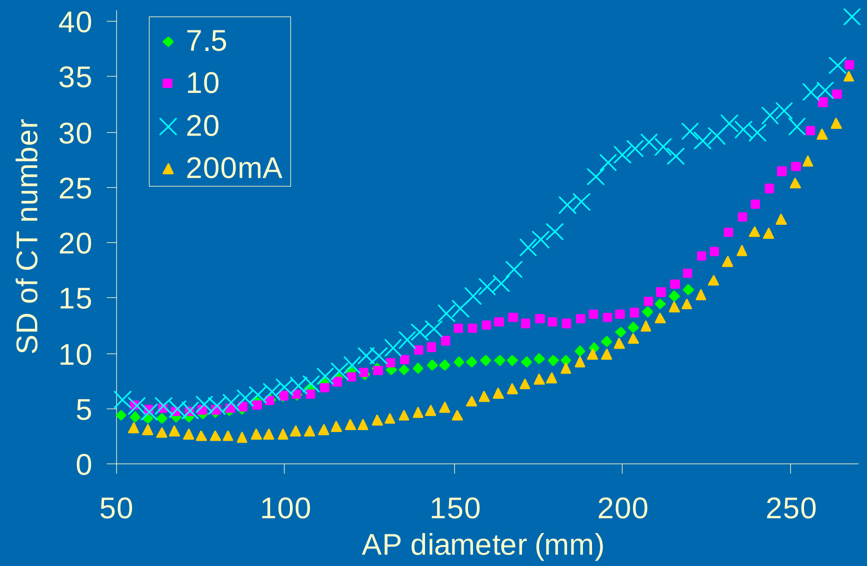
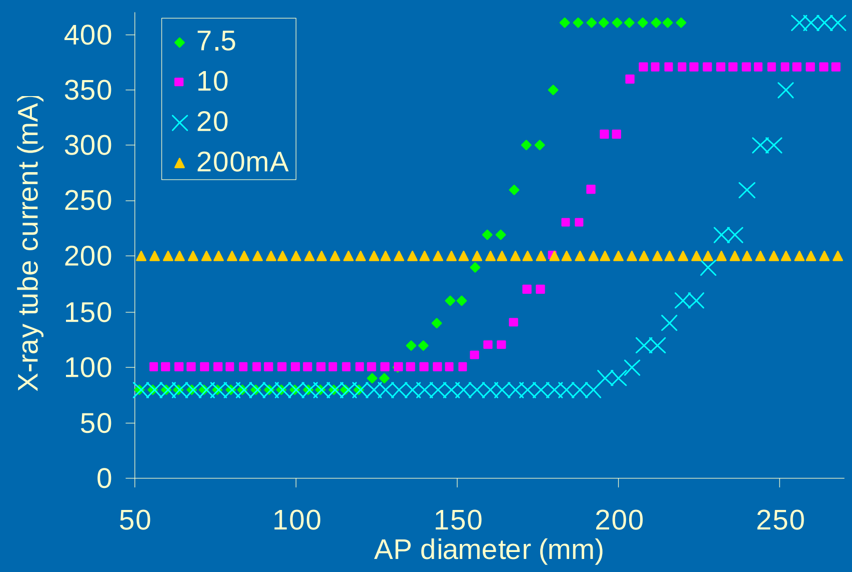
Beware older scanners & software!

Results - Toshiba





- Performance of 16 slice Toshiba was found to be different in respect to the Toshiba 64 slice scanners.
- Older software version, different AEC system interface.
- mA modulation only occurs over a small AP diameter range (~5cm).
- Point at which mA modulation occurs increases with AP diameter.

Conclusion

- Scanners tested performed consistently with the findings described in the 2005 report by ImPACT[1].
- Machines with apparently identical operation were found to have AEC systems which performed differently.
- Only through the individual testing of each scanner can the true behaviour of its AEC system be established.
- It is therefore essential that users operating each scanner fully understand not only how the relevant manufacturers AEC systems work in general but also how the specific scanner in their department operates.

[1] *CT scanner automatic exposure control systems.* Medicines and Healthcare Regulatory Agency, February 2005. Report 05016

Thank You

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