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Focal Spot Blooming in CT: We Didn't Know We Had a Problem Until We Had a Solution

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DISCLOSURES

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DK 100227	Siemens Healthcare
HR 046158	
RR 018898	

Off Label Usage

None

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Effects of x-ray tube current and voltage on effective focal spot size

- Chaney E, Hendee W, 1974, Journal of Medical Physics, vol 1 page 141
- Hendee W, Chaney E, 1974 Applied Radiology, vol 3, page 25

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Physics of Radiology

- Anthony Wolbarst, 1993
- Page 202
- "A higher tube current may cause blooming of the focal spot, with loss of resolution"

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Medical Imaging Physics 4th Edition

- William Hendee and Russel Ritenour, 2002
- Page 81
- "For most x-ray tubes, the size of the focal spot is not constant. Instead it varies with both the tube current and the voltage applied to the x-ray tube."

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Introduction to Medical Radiographic Imaging

- Robert Pizzutiello, Jr. and John Cullinan, 1993
- Page 22
- "Focal spot size can also be effected by exposure conditions. For instance, the focal spot tends to increase in size ("bloom") at higher mA settings, particularly at lower kVp settings. The selection of a small focal spot at maximum available mA may not provide the image sharpness expected with the small spot."

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Physical Principals of Medical Imaging 2nd Edition

- Perry Sprawls, Jr.,
- Page 272-273
- "A common characteristic of many focal spots is that they undergo a change in size with changes in mA and kVp. This effect is known as blooming. If the size of a focal spot is measured at a relatively low tube current, the size of during operation during higher tube current values can be significantly larger. The amount of blooming with an increase in tube current varies from tube to tube. In some tubes, the blooming of the focal spot in one direction is more than in the other. Blooming is generally greater for small focal spots. kVp generally has less effective focal spot size than current. Some focal spots undergo a slight reduction in size with increased kVp."

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Background

- Focal spot blooming
  - Enlargement of focal spot size as mA is increased
  - At fixed mA and decreasing kV, focal spot size increases
  - Potential concern for low kV imaging
  - While nobody talks about focal spot blooming in CT, we have radiologists who avoid 80 kV imaging as they perceive it to be blurrier
- Vectron tube of new Siemens SOMATOM Force scanner designed to reduce focal spot blooming
  - Quadrupole dynamic focusing
  - Shortened distance between focusing unit and anode

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Purpose

- Investigate influence of varying tube current and tube potential on CT spatial resolution
- Evaluate ability of dynamic focal spot control to reduce focal spot blooming effects

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Spatial resolution assessed on 7 scanners

Scanner	Manufacturer	Scanner model	Tube model	Maximum tube current (mA) at 80 kV	Nominal focal spot size (mm)
A	Siemens	Force	Vectron	1300	0.8
B	Siemens	Definition Flash	Straton MX P	650	1.2
C	Siemens	Definition AS+	Straton MX (P46)	650	1.2
D	Siemens	Sensation 64	Straton Z	500	1.2
E	Siemens	Sensation 16	Dura Akron Q	370	1.2
F	GE	Lightspeed VCT	Hercules	675	1.2
G	GE	Lightspeed 16	Performix	400	1.2

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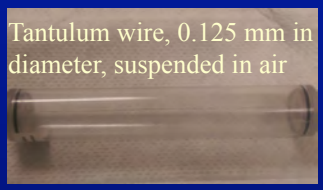
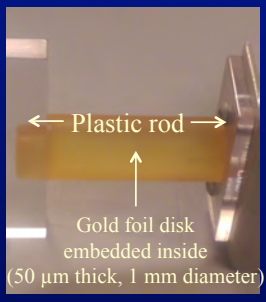
Methods – Phantom Image Acquisition





- In plane spatial resolution was evaluated by measuring the Modulation Transfer Function (MTF)
- Z-axis resolution was evaluated by measuring the Section Sensitivity Profiles (SSP)

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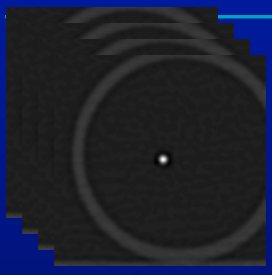
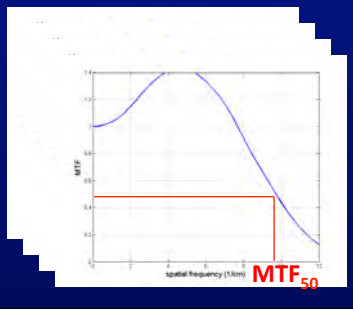
Methods – MTF in Axial Plane





- Wire phantom
  - MTF curves calculated in 10 consecutive axial images
  - Spatial resolution evaluated as MTF at 50% (MTF_{50})
  - Averaged MTF_{50} from 10 curves
  - Process repeated for each tube potential/current combination

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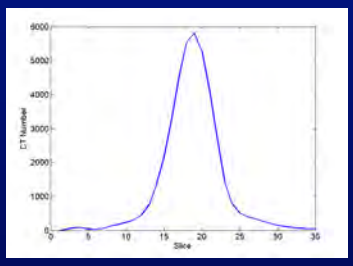
Methods – Slice Sensitivity Profile (SSP)



- Point response phantom
  - Average CT number in ROI drawn inside foil at same location in consecutive images of phantom (0.1 mm increment)
  - Determined full-width-at-half-maximum (FWHM) of slice sensitivity profiles (SSPs) for each tube potential/current combination

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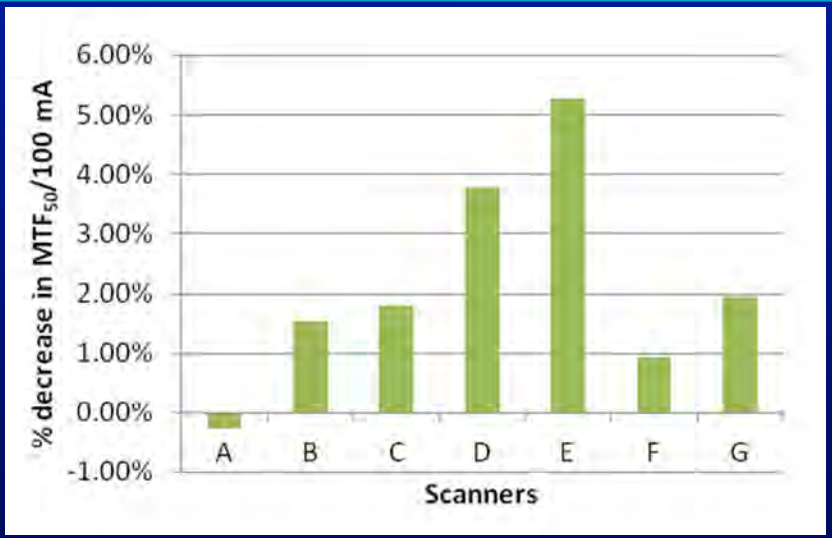
Changes in in-plane resolution



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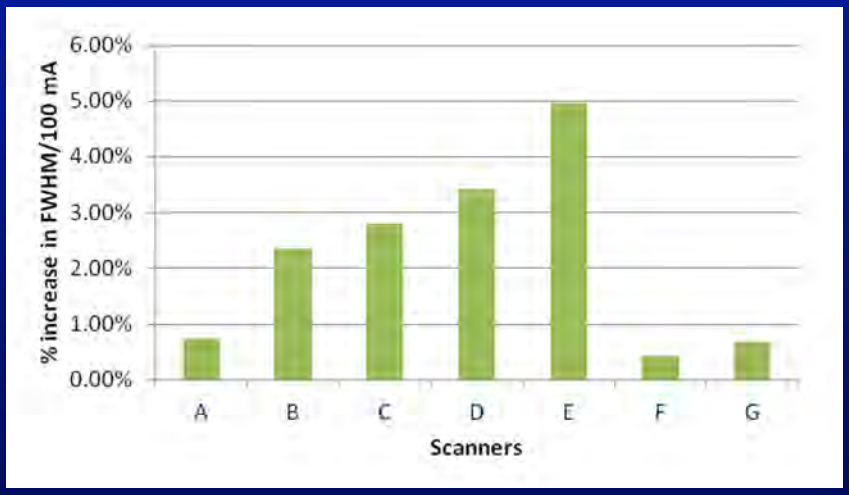
Changes in z-axis resolution



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Methods

- Spatial resolution was assessed in depth on two scanners:

	SOMATOM Force (scanner A)	Definition Flash (scanner B)
Tube	Vectron	Straton
kV	70 – 150 (steps of 10 kV)	70, 80, 100, 120, 140
mA	20 – 1300	20 – 800 (max 500 mA 70 kV)
Nominal FS size	0.8 mm	1.2 mm

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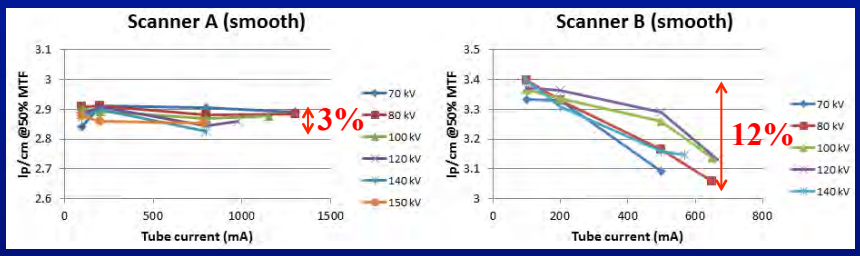
Results – MTF at 50%



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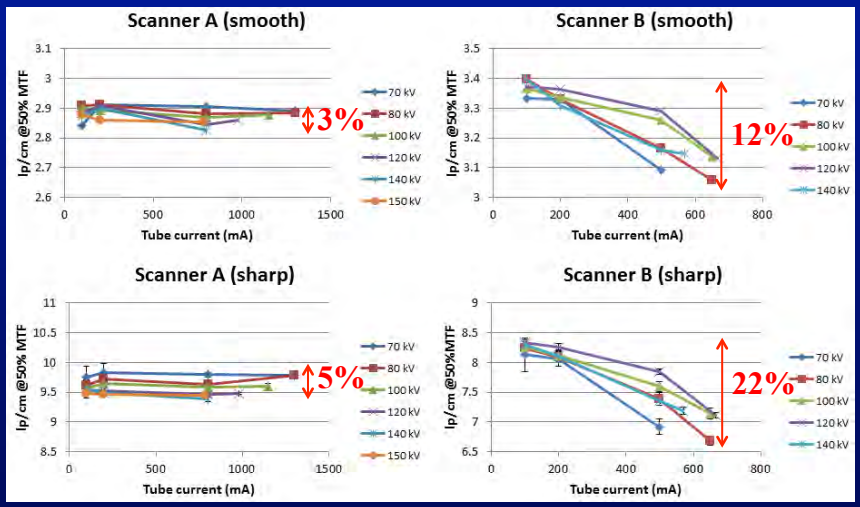
Results – MTF at 50%



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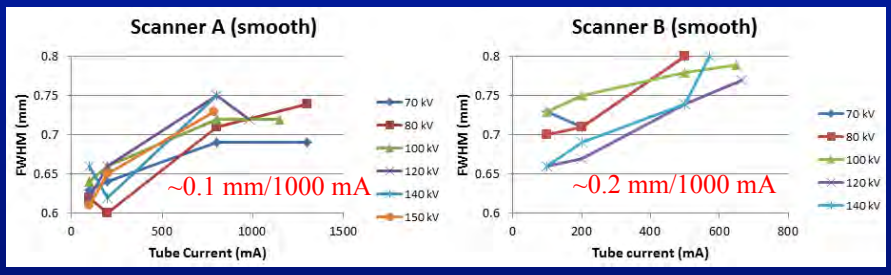
Results – Slice Sensitivity Profile (SSP)



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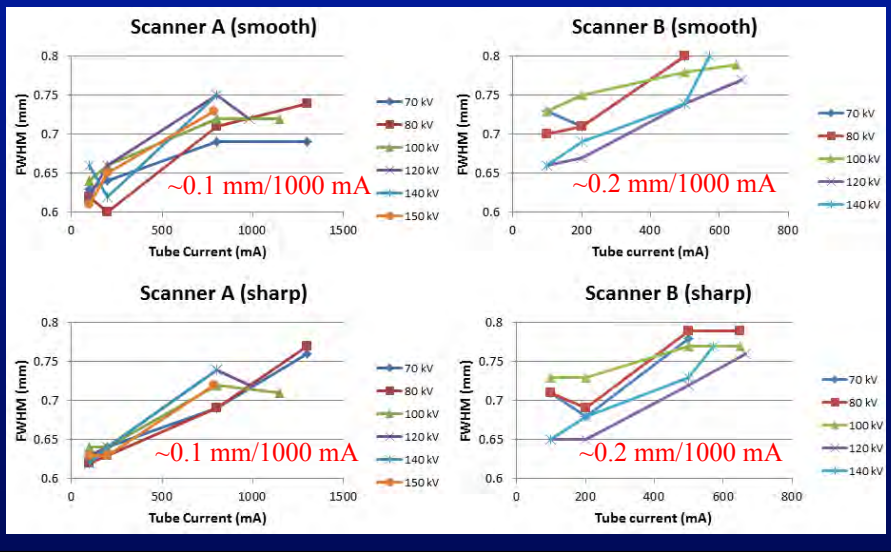
Results – Slice Sensitivity Profile (SSP)



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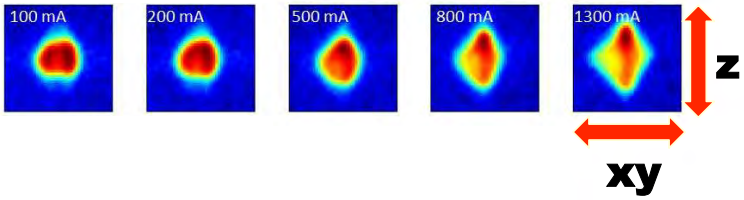
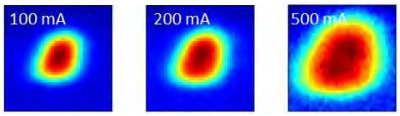
Pinhole Camera Measurements

Scanner A – 70 kV



Scanner B – 70 kV



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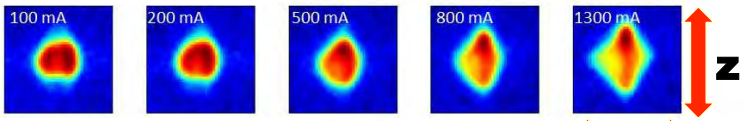
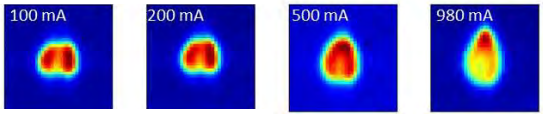
Pinhole Camera Measurements

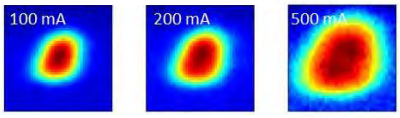
Scanner A – 70 kV



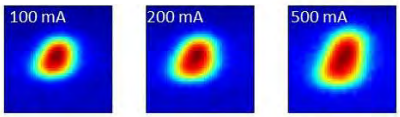
Scanner A – 120 kV



Scanner B – 70 kV



Scanner B – 120 kV



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Summary

- Reduced focal spot blooming is important for controlling spatial resolution as mA is increased
- Technical measures to limit focal spot blooming are important, especially for low kV/high mA protocols (e.g. children, small adults, dual-energy scanning)
- Focal spot shaping technology helped to reduce blooming effects in the axial plane

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http://mayoresearch.mayo.edu/ctcic