

Iterative Reconstruction with Philips iDose

Characterising Image Quality in Attempting to Realise its Potential

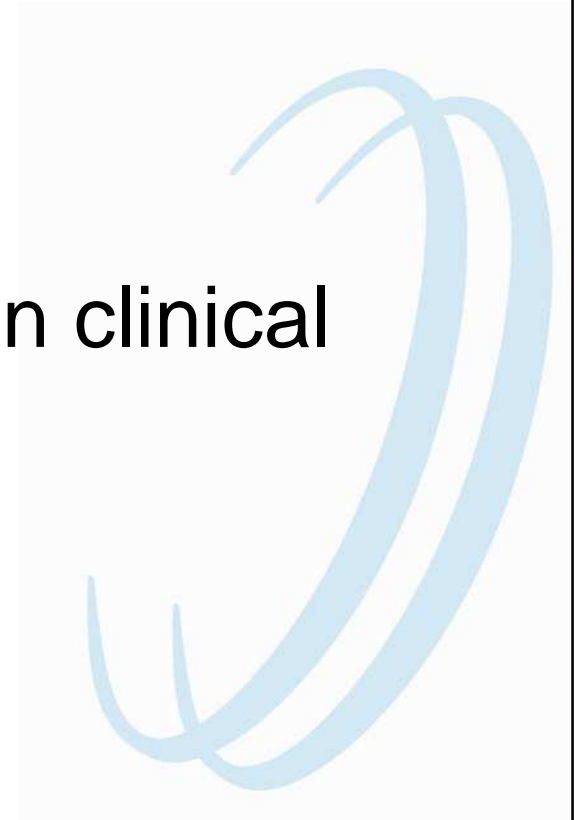
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Belfast Health and
Social Care Trust

Outline

- Preamble
- Image Quality Analysis
 - Noise & CT Number
 - Spatial resolution
 - NPS
- Predicting the effect of iDose on clinical protocols
- Current & future work



Noise & CT Number

- Test conditions
- Base parameters:
 - Axial, 120kVp, 16x0.625mm, 10mm, 300mAs, Standard (B), 250mm FOV, FBP
- Vary mAs/recon kernel/slice width at range of iDose levels
- Catphan uniformity module (solid water)
- Mean pixel value (CT#) and standard deviation (σ) in ROI $\sim 2000\text{mm}^2$
- Average over 5 acquisitions (averaged over all images in 1 acquisition for slice width)

CT Number

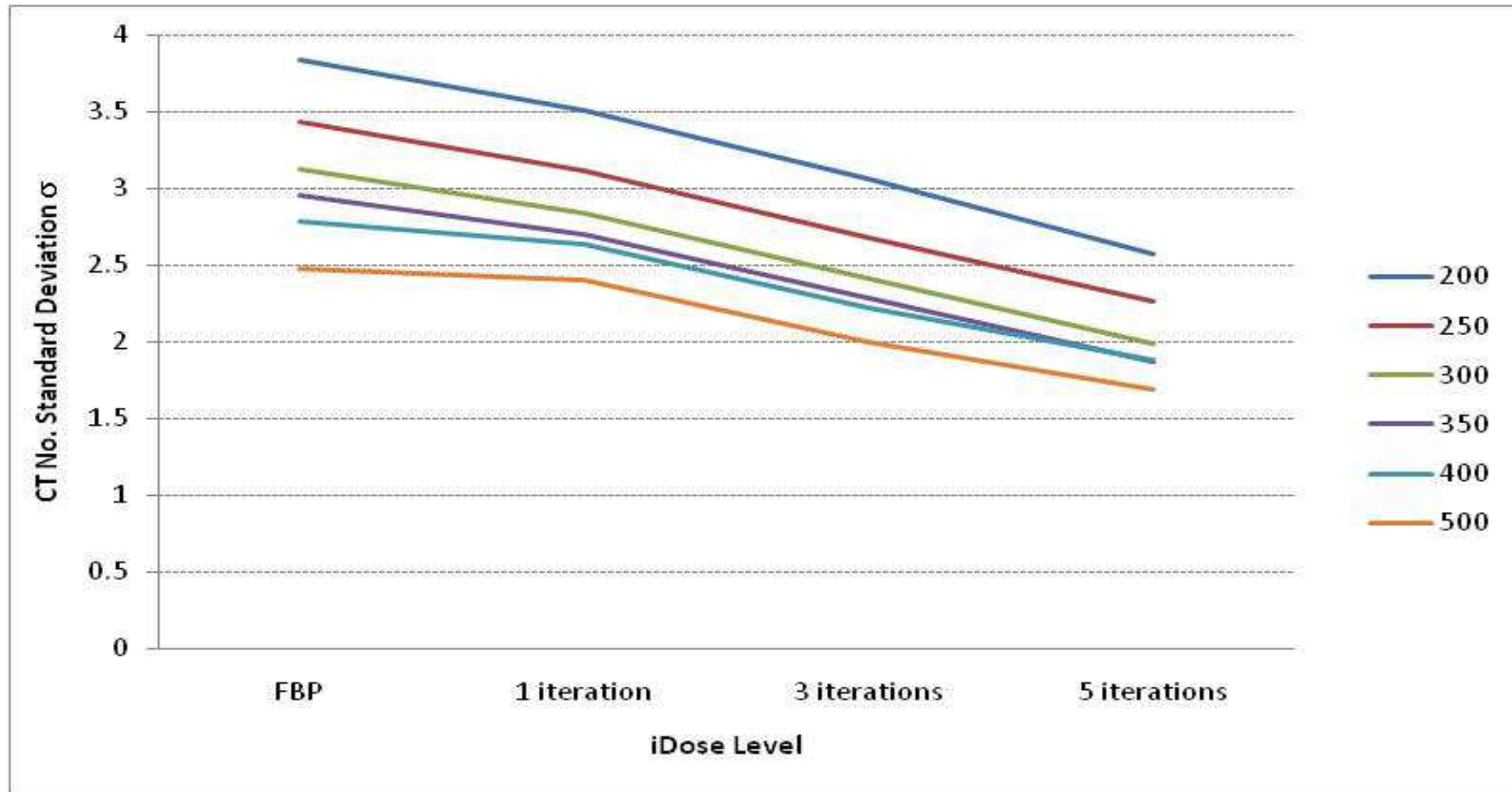
- iDose has no significant effect on HU

iDose Level	CT# across mAs range Mean (Min-Max)	CT# across recon kernels Mean (Min-Max)	CT# across slice widths Mean (Min-Max)	CT# across parameters Mean
FBP	17.2 (17.2-17.3)	17.3 (16.3-18.3)	17.5 (17.3-17.7)	17.3
1	17.3 (17.3-17.4)	17.3 (16.3-18.3)	17.6 (17.3-17.8)	17.4
3	17.3 (17.3-17.4)	17.3 (16.3-18.3)	17.6 (17.3-17.8)	17.4
5	17.2 (17.2-17.3)	17.3 (16.3-18.3)	17.5 (17.3-17.8)	17.3



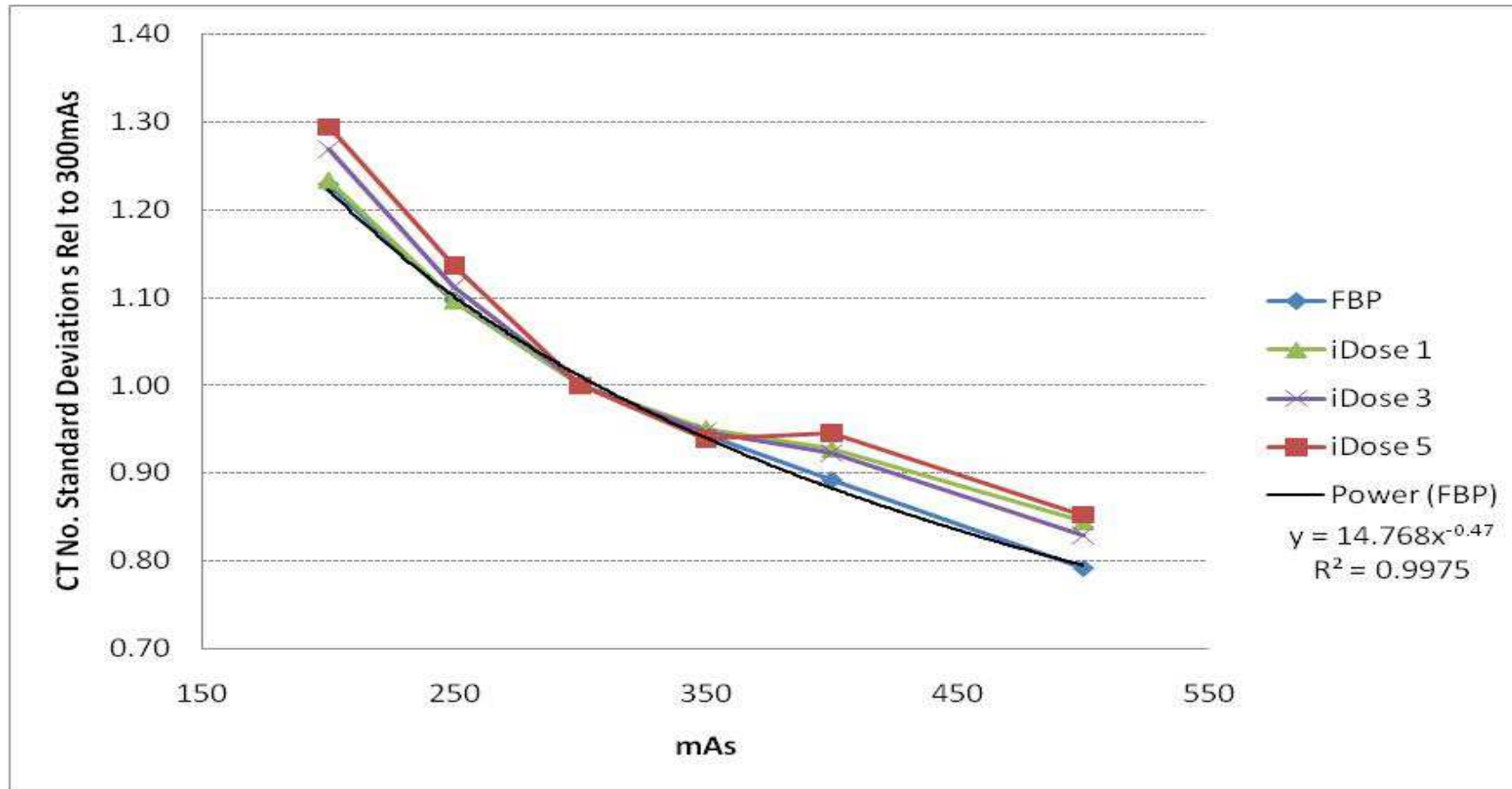
Noise and mAs

Measured σ



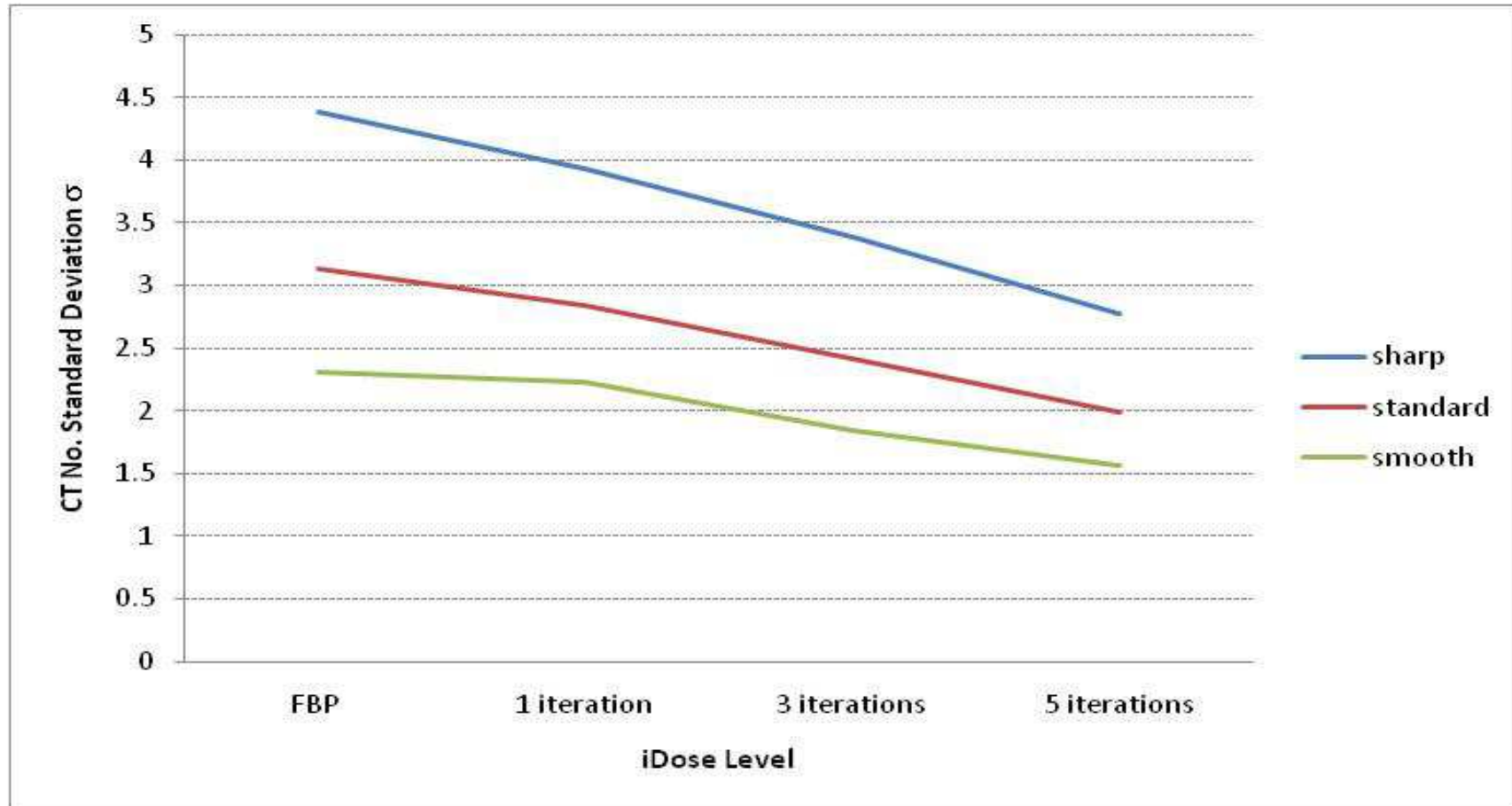
Noise and mAs

σ relative to $\sigma_{300\text{mAs}}$



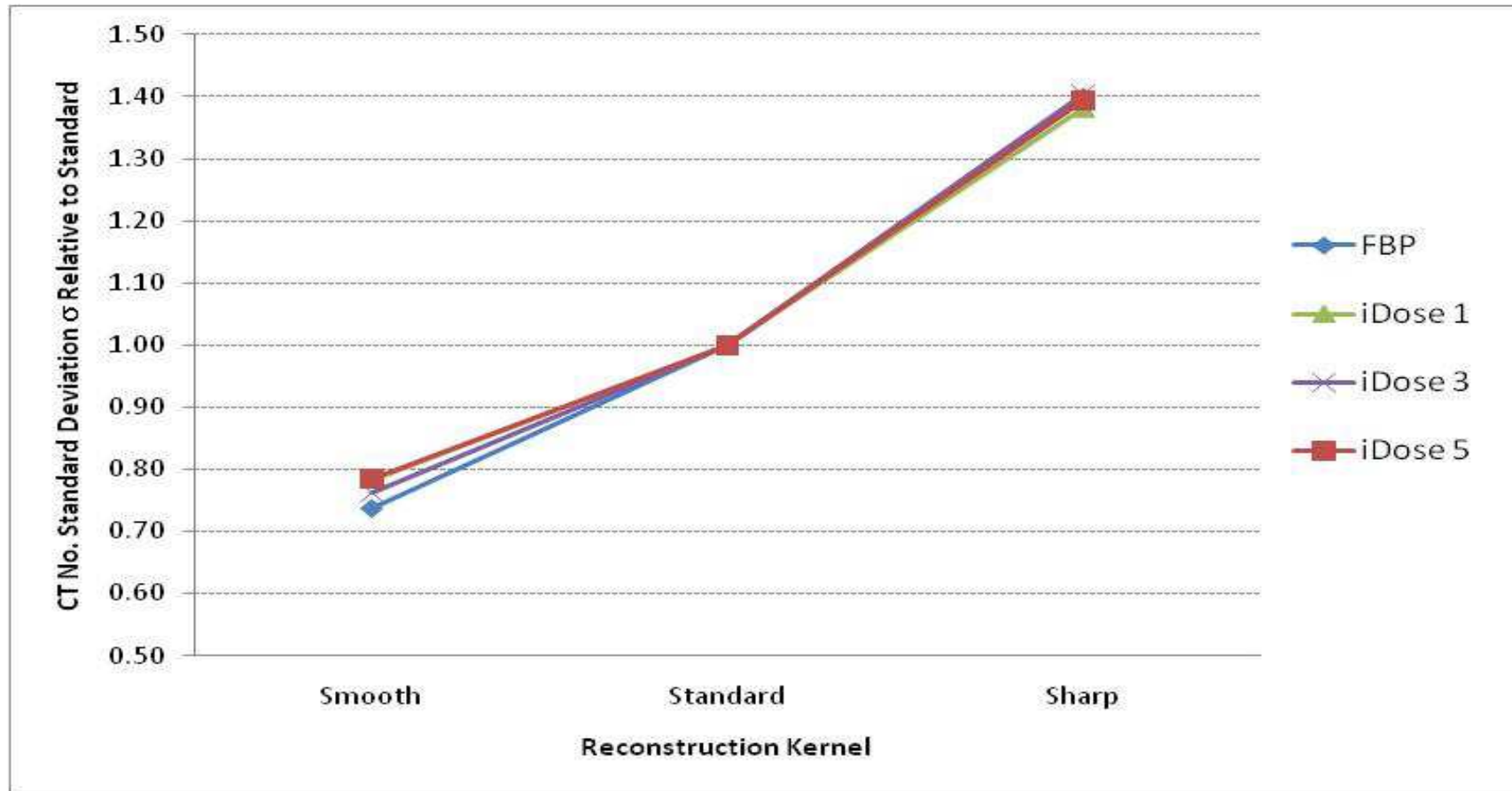
Noise and Recon Kernel

Measured σ



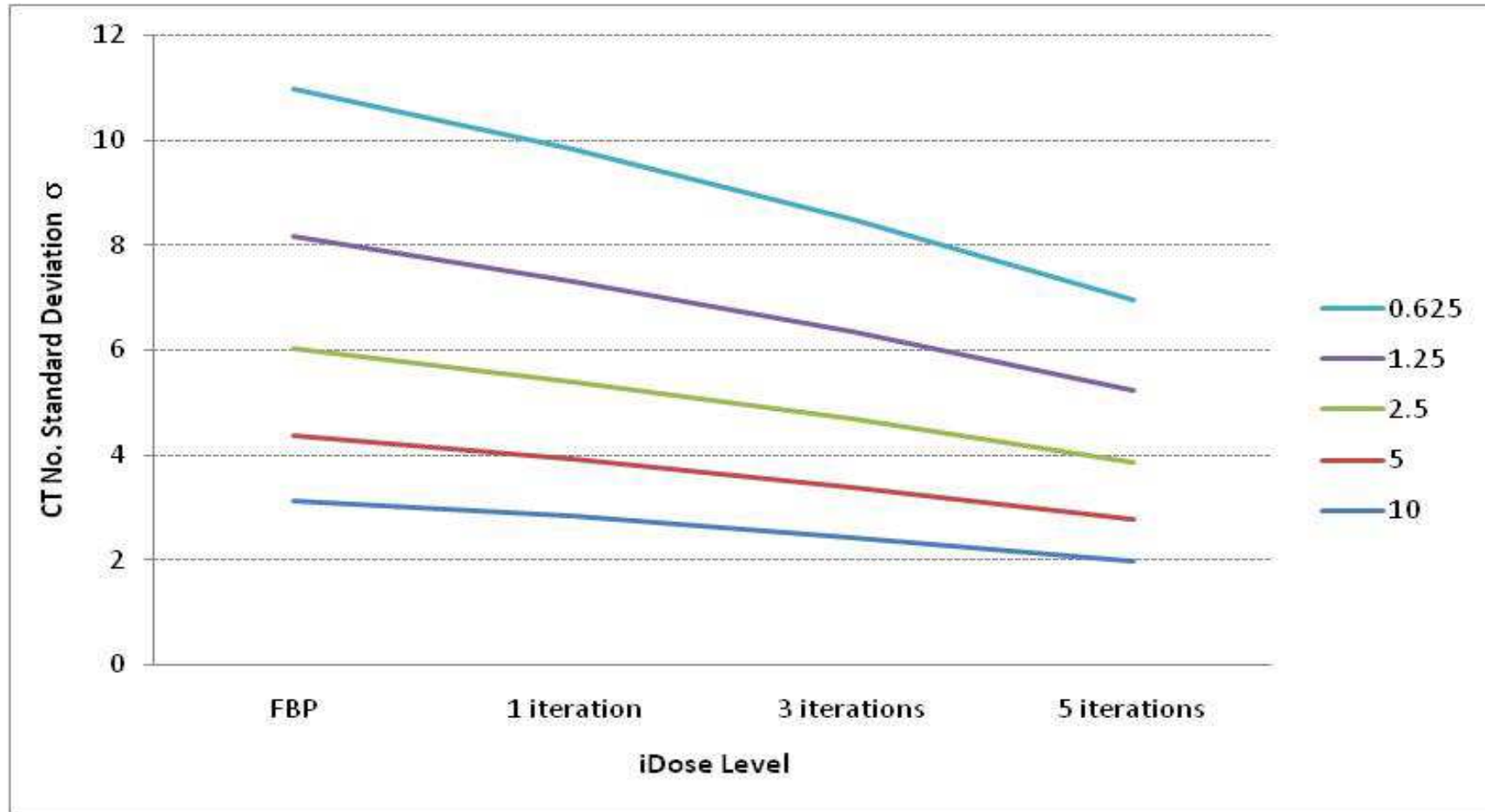
Noise and Recon Kernel

σ relative to σ_{Standard}



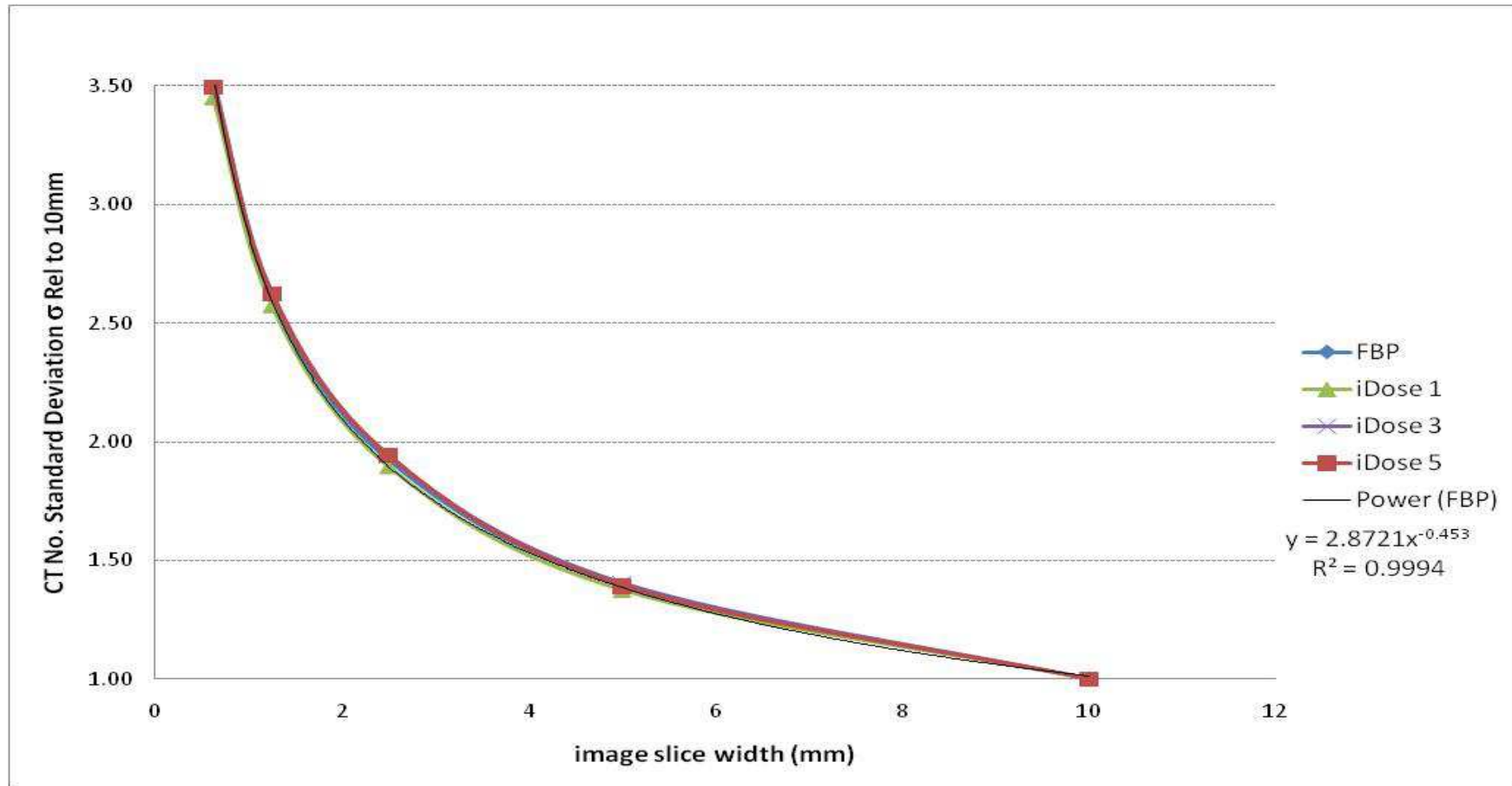
Noise and Slice Width

Measured σ



Noise and Slice Width

σ relative to $\sigma_{10\text{mm}}$



FBP and iDose

- σ relative to σ_{FBP}

iDose Level	Rel σ across mAs range Mean (Min-Max)	Rel σ across recon kernels Mean (Min-Max)	Rel σ across slice widths Mean (Min-Max)	Rel σ across parameters Mean
1	0.93 (0.91-0.97)	0.92 (0.90-0.96)	0.92 (0.91-0.95)	0.92
3	0.79 (0.77-0.81)	0.78 (0.77-0.80)	0.78 (0.77-0.80)	0.78
5	0.66 (0.63-0.68)	0.65 (0.63-0.68)	0.65 (0.63-0.67)	0.65



FBP and iDose: Philips Values

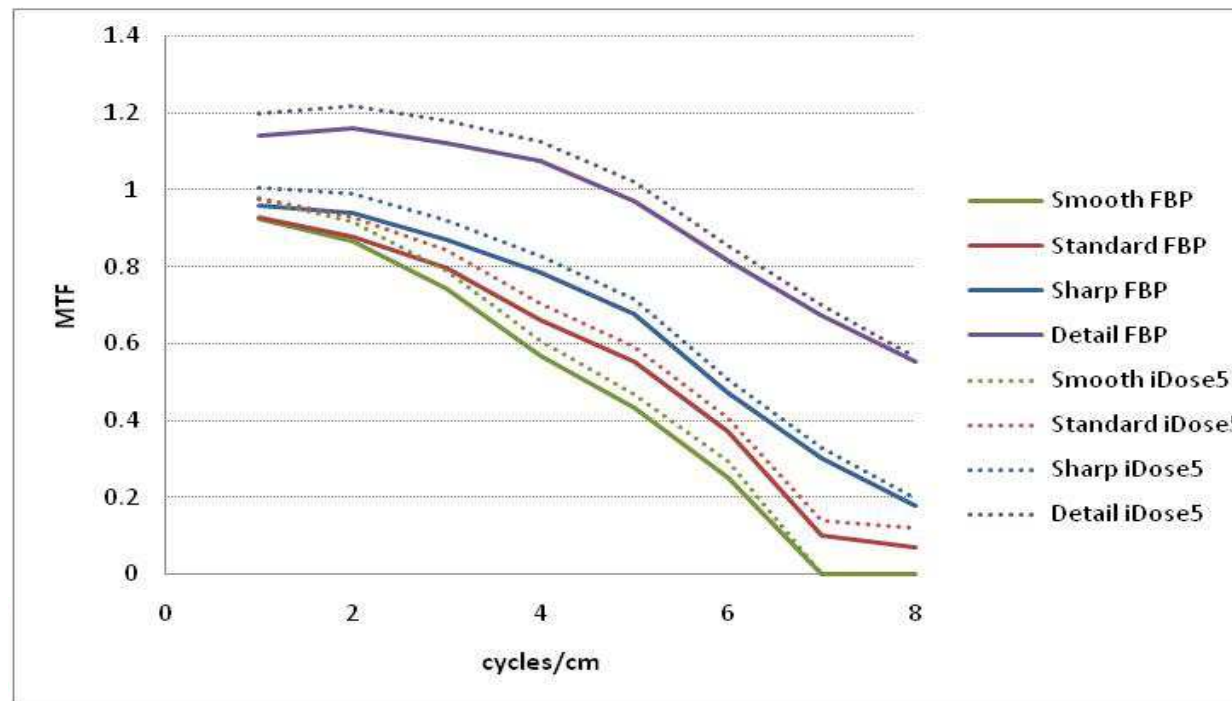
- % noise reduction table from Philips iDose manual

	% Noise Reduction wrt FBP						
iDose Level	1	2	3	4	5	6	7
Philips Manual	0-13	13-19	19-25	25-33	33-41	41-50	50-62
Measured	8		22		35		

- Good agreement between measured values & Philips

Spatial Resolution (x-y)

- Catphan line pair pattern
- Vary recon kernel at range of iDose levels
- MTF using Droege and Morin method (Med Phys 9(5) 758-780)



Spatial Resolution (x-y)

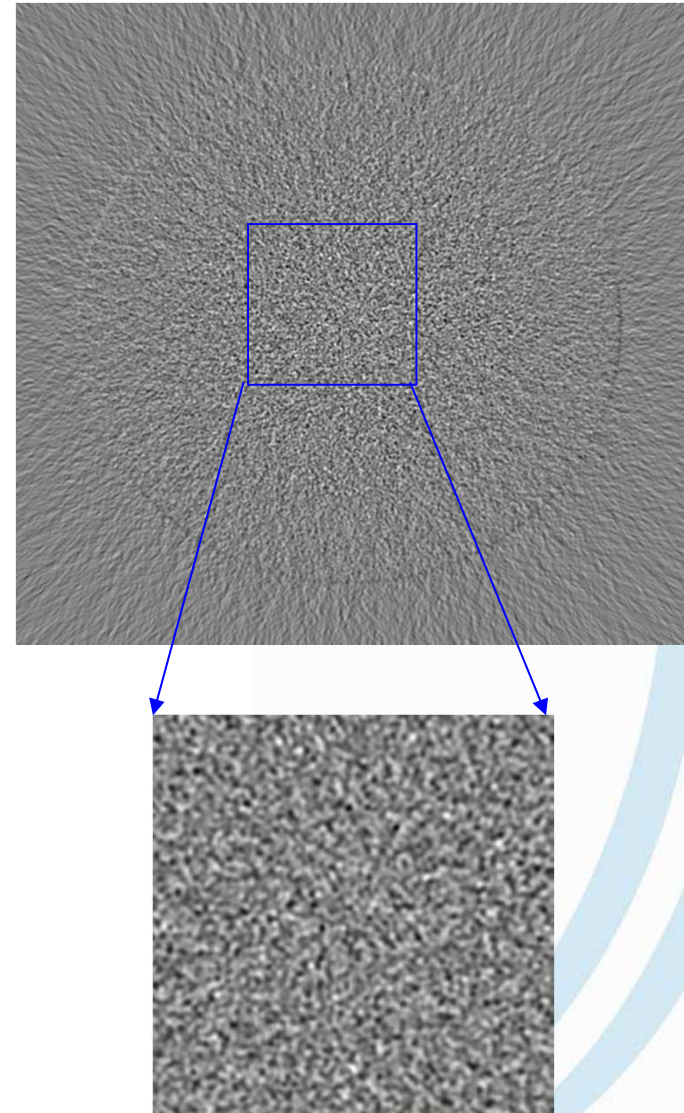
- Catphan bead
- Vary iDose levels and mAs at Standard (B) recon kernel
- MTF using in-house IDL software
- iDose has no significant effect on MTF

61 mAs	MTF50	MTF10
FBP	2.95	5.42
iDose 1	3.10	5.67
iDose 3	3.06	5.62
iDose 5	3.26	5.98

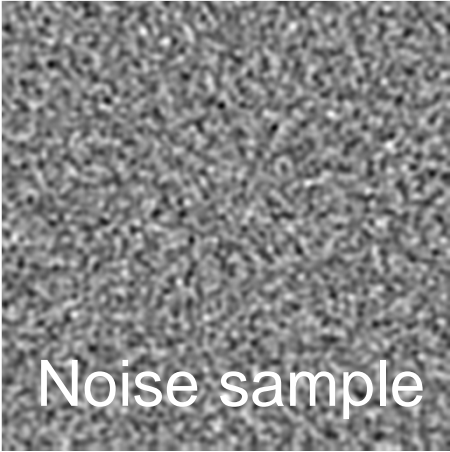
FBP	MTF50	MTF10
61 mAs	2.95	5.42
75 mAs	3.03	5.62
85 mAs	3.11	5.72
98 mAs	3.29	6.08

Determining CT NPS

- Series of CT images of uniform phantom
- Mask subtract one of the images to remove structure noise
- Extract 128x128 pixel array from centre of each subtracted image



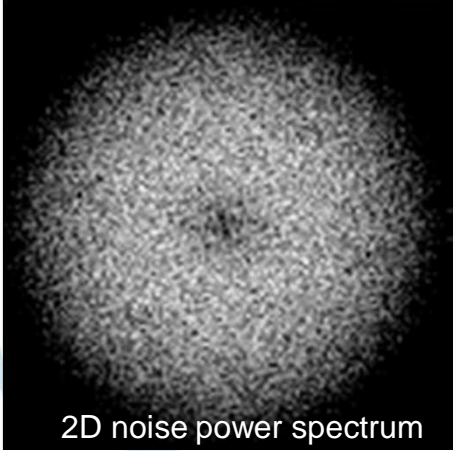
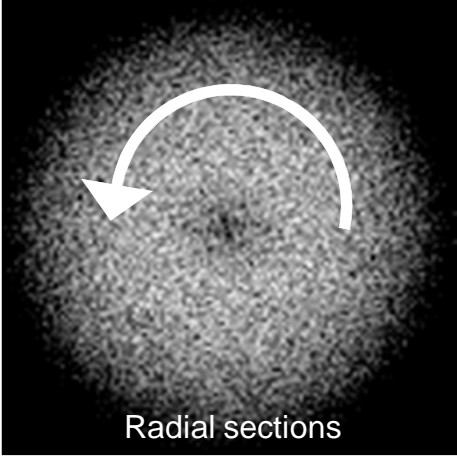
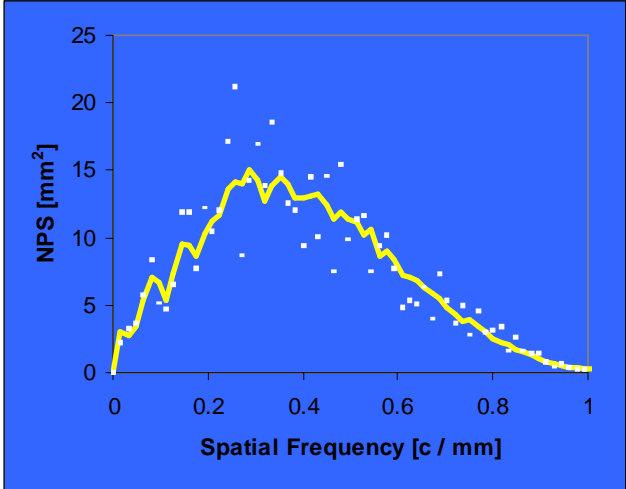
Determining CT NPS



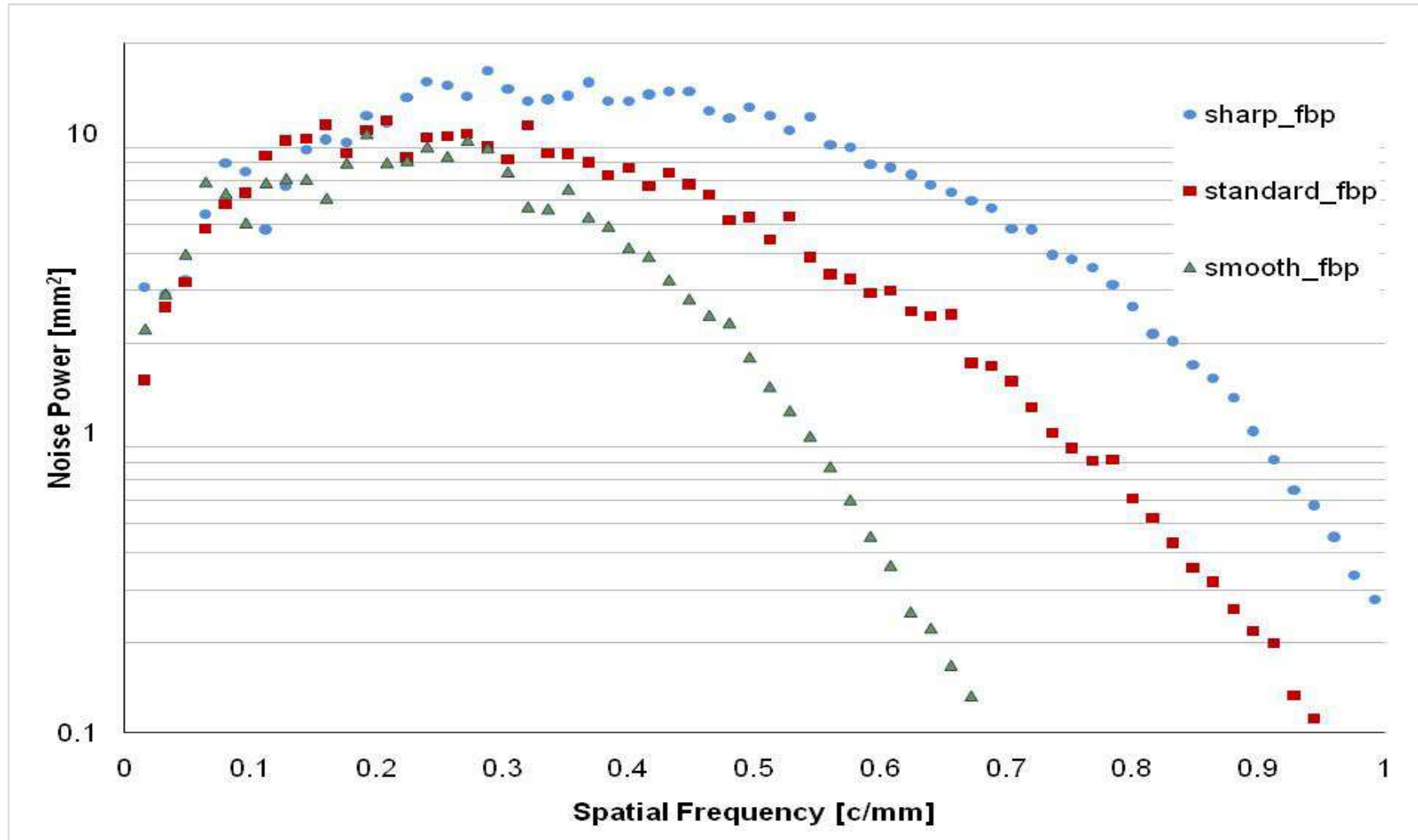
|2D FFT|²

Ensemble Average

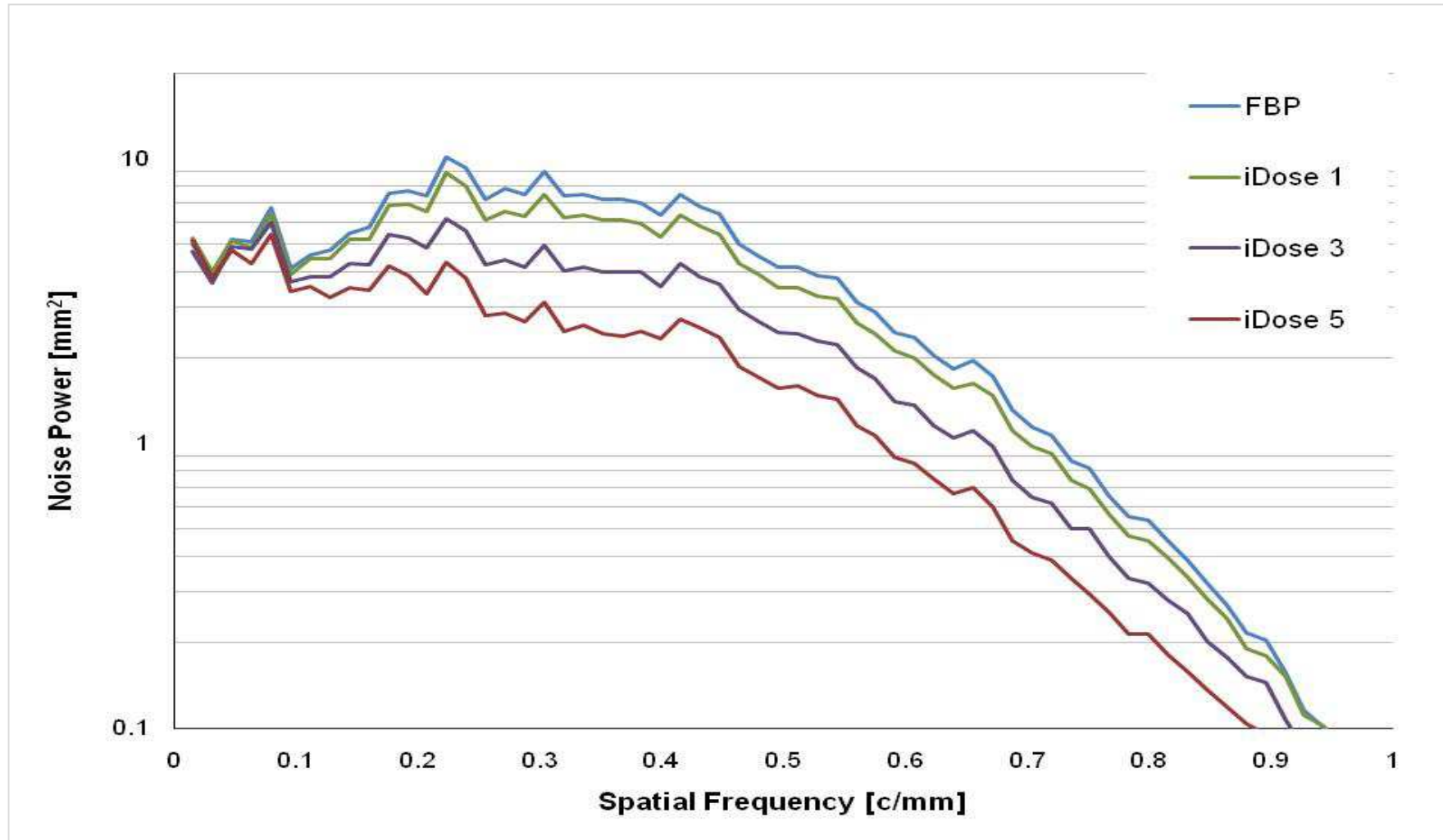
$$\frac{\Delta x \cdot \Delta y}{N^2 \cdot n}$$



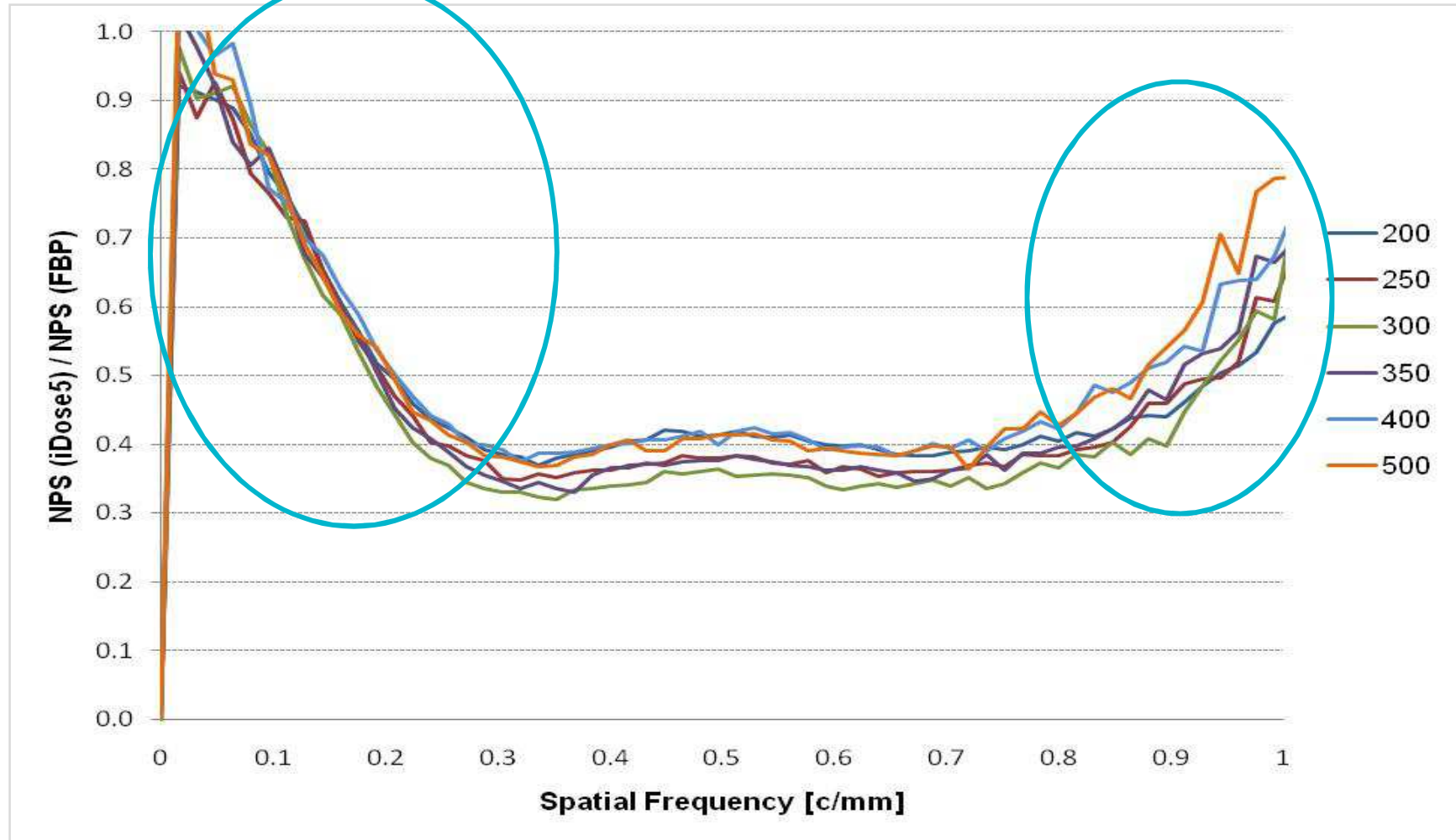
NPS- Recon Kernel (FBP)



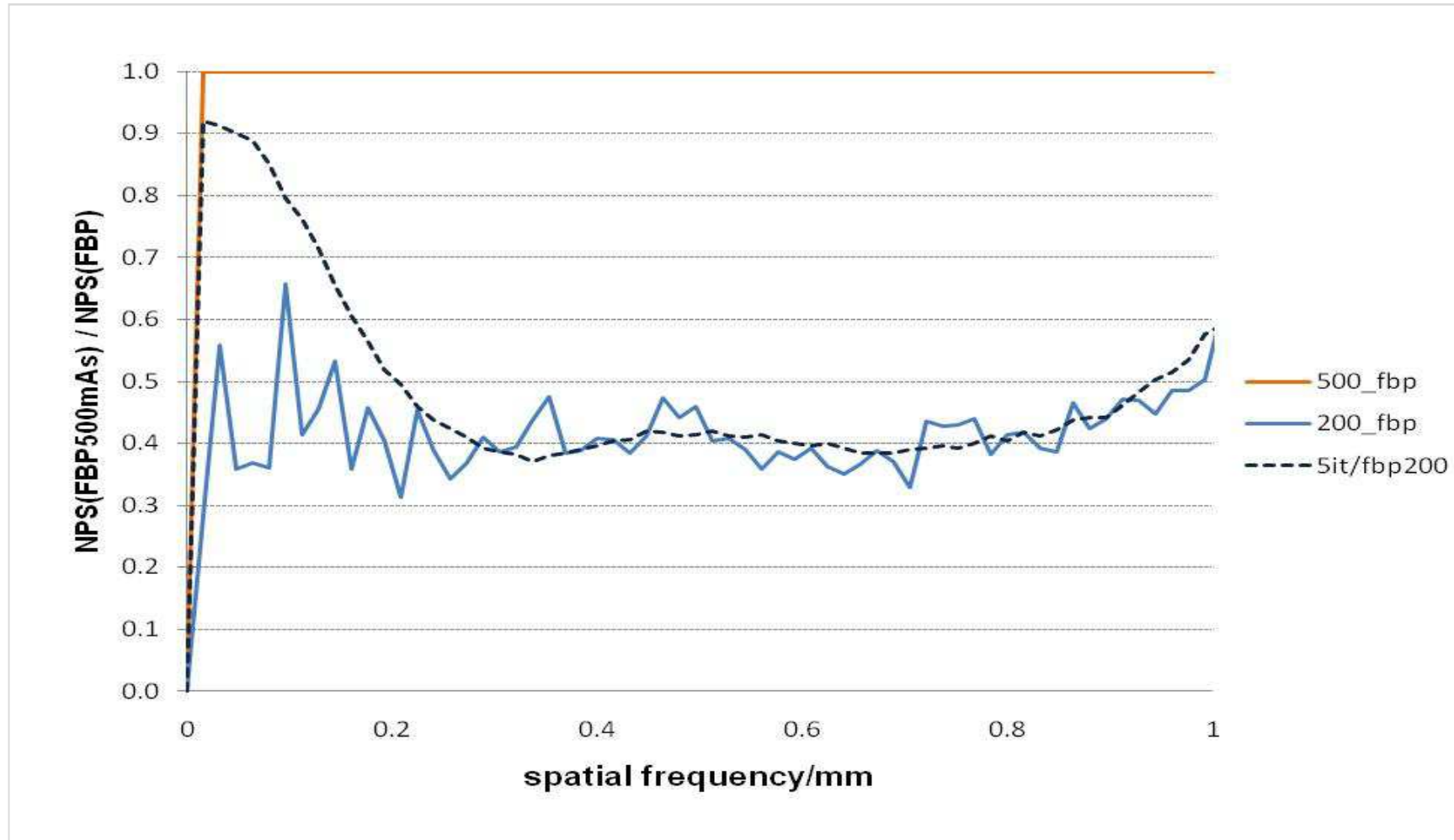
NPS- iDose Level (350 mAs)



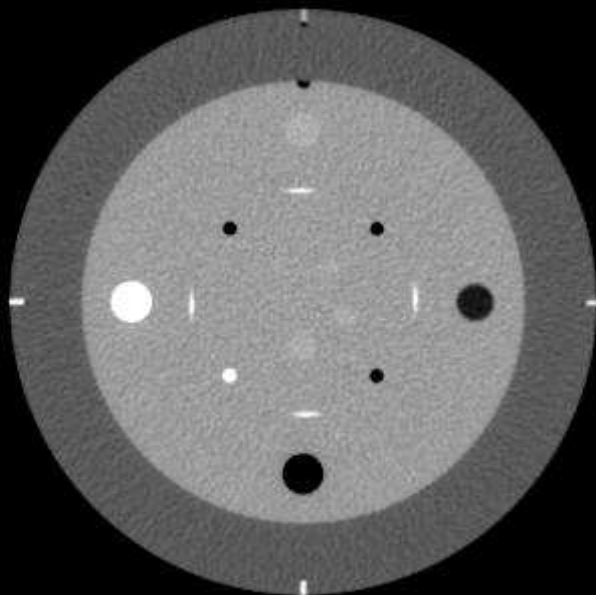
NPS Ratio: iDose5 vs FBP



NPS Ratio: 500mAs v 200mAs

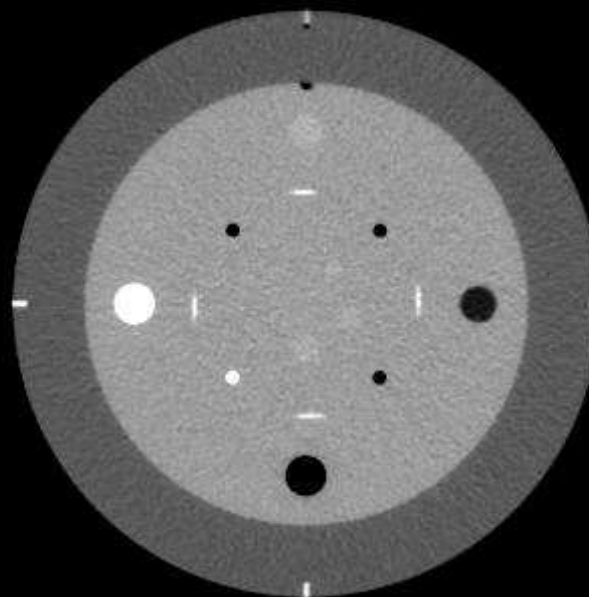


98 mAs FBP



$\sigma = 7.7$

61 mAs iDose3



$\sigma = 7.7$



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Predicting the Effect of iDose on Clinical Protocols

- Initial results indicate no significant change in spatial resolution with iDose level
- Can we use the relative σ relationships derived from test data to estimate the change in noise for clinical protocols?
- Lots of assumptions: helical behaves the same as axial, noise factors are multiplicative, relative values independent of FOV, helical pitch, beam collimation, kV

Noise Corrections

- mAs

FBP relative σ trendline [$\sigma_{mAs}/\sigma_{300} = f(mAs)$]

- Slice width

FBP relative σ trendline [$\sigma_{sw}/\sigma_{10} = f(sw)$]

- Recon kernel (A, B or C)

Relative σ [$\sigma_{A, B \text{ or } C}/\sigma_{A, B \text{ or } C}$]

- iDose Level

Average relative σ [$\sigma_{FBP}/\sigma_{iDose}$]



Predicting Change in Noise

Protocol #1 Abdo-Pelvis

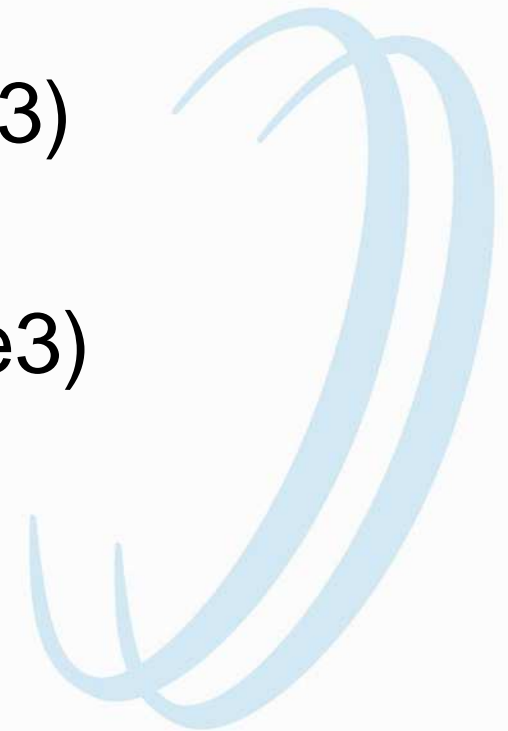
- Parameters: 120kVp, Px 1.172, 64x0.625mm, 3mm image, 350 FOV, B kernel
- Old Protocol*: 98mAs/slice, FBP
- New Protocol*: 61mAs/slice, iDose3 (40% dose saving)
- mAs noise correction = 1.25
- iDose noise correction = 0.78
- Total noise correction = $1.25 \times 0.78 = 0.98$



Predicting Change in Noise

Protocol #1 Abdo-Pelvis

- Catphan uniformity module, ROI 2000mm²
- Measured σ (98mAs/slice, FBP)
7.7 HU
- Predicted σ (61mAs/slice, iDose3)
 $7.7 \text{ HU} \times 0.98 = 7.5 \text{ HU}$
- Measured σ (61mAs/slice, iDose3)
 7.7 HU (*within 3% of predicted*)



Predicting Change in Noise

Protocol #2 CTA 75%

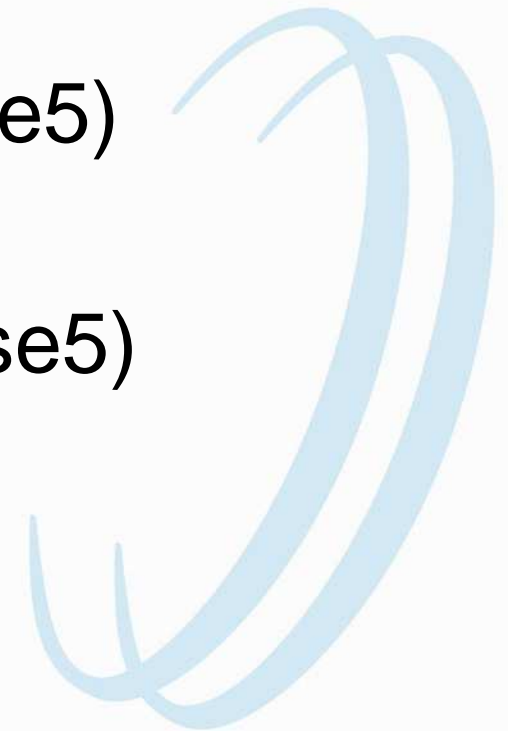
- Parameters: 120kVp, Px 0.25, 64x0.625mm, 0.9mm image, 220 FOV, XCB kernel
- Old Protocol*: 1080mAs/slice, FBP
- New Protocol*: 800mAs/slice, iDose5 (20% dose saving)
- mAs noise correction = 1.15
- iDose noise correction = 0.65
- Total noise correction = $1.15 \times 0.65 = 0.75$



Predicting Change in Noise

Protocol #2 CTA 75%

- Catphan uniformity module, ROI 2000mm²
- Measured σ (1080mAs/slice, FBP)
11.5 HU
- Predicted σ (800mAs/slice, iDose5)
 $11.5 \text{ HU} \times 0.75 = 8.6 \text{ HU}$
- Measured σ (800mAs/slice, iDose5)
8.3 HU (*within 4% of predicted*)



Predicted % Noise Change for Upgraded Protocols (1)

Ulster Hospital, Belfast, UK. B64 upgrade protocols

Protocol name	Version	kVp	mAs	CTDI	iDose	slice thickness	filter	% mAs saving	% CTDi saving	% Noise Change
Helical Brain	Original	120	350	55.6	n/a	3mm	UB			
	iDose	120	250	39.7	Level 2	3mm	UB	29%	29%	0%
HRCT Axial	Original	120	200	3.2	n/a	1.25mm	L			
	iDose	120	75	1.2	level 3	1.25mm	L	63%	63%	+24%
CTPA	Original	120	130	8.5	n/a	1.4mm	B			
	iDose	120	80	5.2	Level 2	2mm	C	38%	39%	+28%
Lung Nodule	Original	120	100	6.7	n/a	2mm	C			
	iDose	120	50	3.3	Level 3	2mm	C	50%	51%	+9%
CAP	Original	120	120	7.9	n/a	3mm	B			
	iDose	120	60	3.9	Level 3	2mm	B	50%	51%	+31%

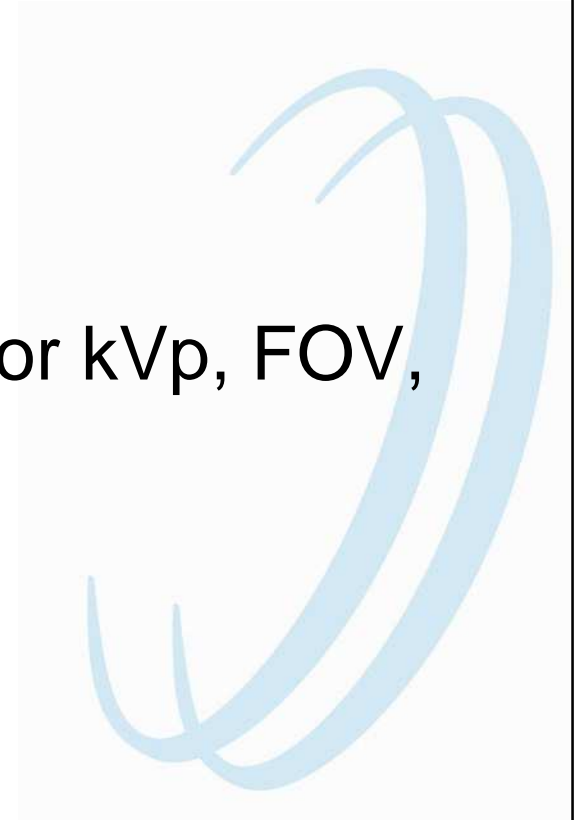
Predicted % Noise Change for Upgraded Protocols (2)

Ulster Hospital, Belfast, UK. B64 upgrade protocols

Protocol name	Version	kVp	mAs	CTDI	iDose	slice thickness	filter	% mAs saving	% CTDi saving	% Noise Change
Calcium Score	Original	120	55	3.7	n/a	2.5mm	B			
	iDose	120	25	1.7	Level 4	2.5 mm	B	55%	54%	+4%
Cardiac CTA helix	Original	120	800	52.3	n/a	0.9mm	XCB			
	iDose	120	400	26.2	Level 4	0.9mm	XCB	50%	50%	0%
S&S Cardiac CTA	Original	120	210	17.6	n/a	0.9mm	XCB			
	iDose	120	100	8.4	Level 4	0.9mm	XCB	52%	52%	+2%
Coronary CTA HR	Original	120	800	52.3	n/a	0.67mm	XCD			
	iDose	120	800	52.3	Level 3	0.67mm	CD	0%	0%	not predicted

Current & Future Work on iDose

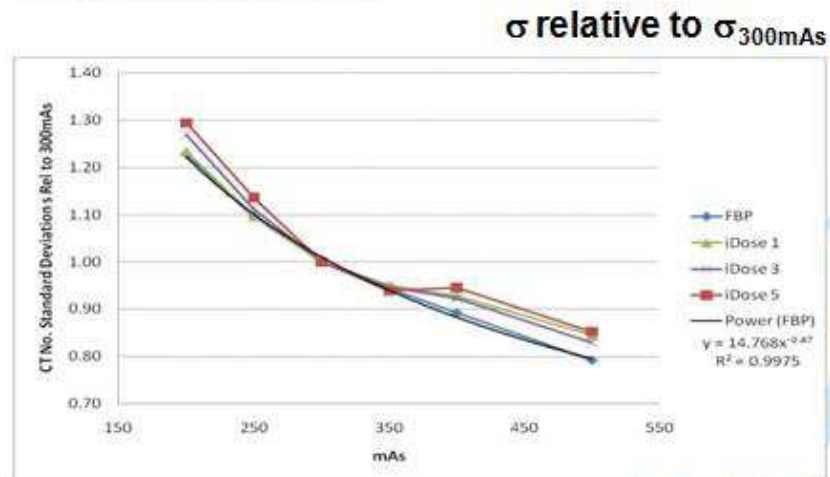
- Assess upgraded clinical protocols
 - Do predicted noise values hold?
- Assess helical
 - Do axial σ relationships hold?
- Expand on axial test data
 - Do relative σ relationships hold for kVp, FOV, sharper kernels?



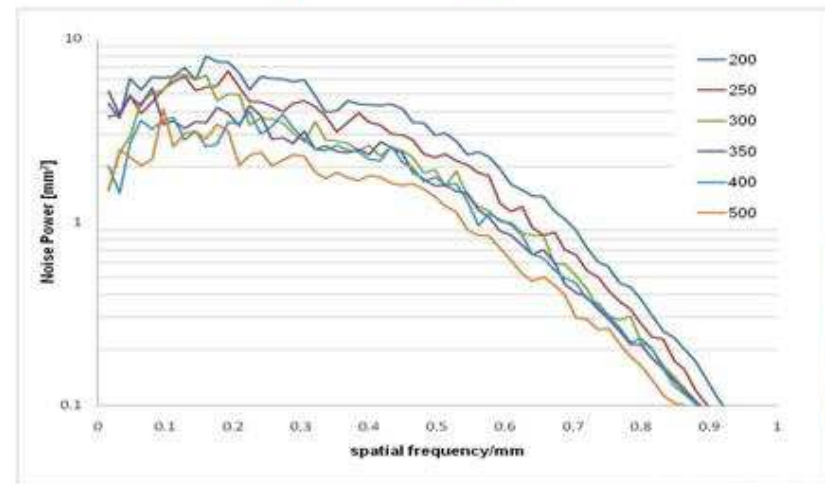
Current & Future Work on iDose

- Evaluation of x-y-z spatial resolution
 - Wider range of kernels, helical & axial
- Investigate NPS/rel σ mAs anomalies

Noise and mAs



NPS-mAs (iDose 5)



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Further information contact either author at
belfasttrust.hscni.net

