Dual Energy CT for the assessment of coronary artery disease and cardiac perfusion. Initial observations and assessment in phantoms and patients.

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A Radiologist's alternative title…..

Gemstone Spectral Imaging In Cardiac Disease

Does it address a clinical need or is it "toys for the boys"?

Introduction

- November 2009 New GE HD750 CT scanner
- Acceptance tests included standard tests + ASiR
- April 2010 “the arrival of GSI”
- End of 2011 (agreed to use GSI for specific clinical requirements for MAR)
- Early 2012 GE put on GSI course
- 2012 – VEO
- To date only ASiR and GSI limited to MAR is in routine clinical use within this hospital. VEO has been recently assessed in phantoms and patients as research studies.

GSI for cardiac applications

- Calcium subtraction
- Assessment of myocardial perfusion (diagnosis of ischaemia/infarct)
- Assessment of delayed enhancement
- Does keV imaging add anything to diagnosis?

- Limited evidence, where exists, normally for 2 tube sysetms (e.g. Siemens Flash)

Cardiac CT

- Cheap: £250 vs £1600 Invasive angiography
- Fast: 20 minute slots vs 5 per 4 hours for ICA
- Non-invasive
- Preferred by patients
- Ability to exclude disease @100%

NICE Guidelines March 2010

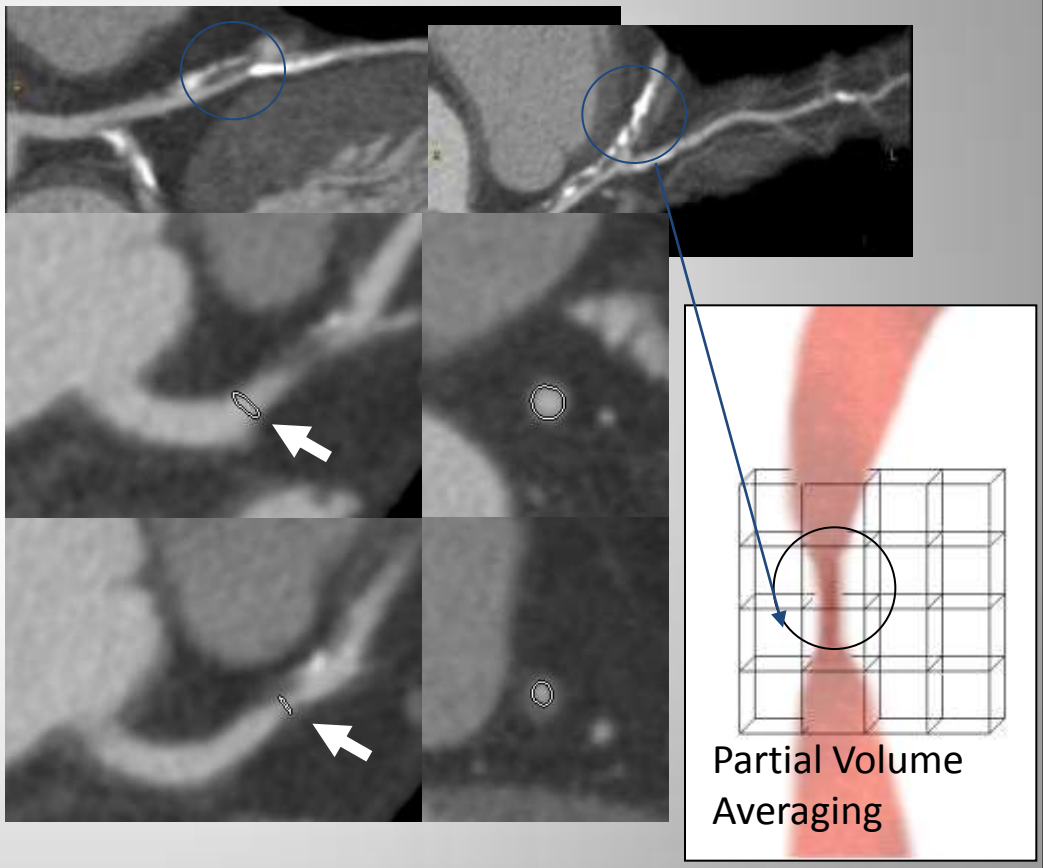
estimated likelihood of CAD is 10–29%	estimated likelihood of CAD is 30–60%	estimated likelihood of CAD is 61–90%
offer CT as the first-line diagnostic investigation	offer functional imaging as the first-line diagnostic investigation	offer invasive coronary angiography as the first-line diagnostic investigation

ASSESSMENT AND INVESTIGATION OF RECENT ONSET CHEST PAIN OR DISCOMFORT OF SUSPECTED CARDIAC ORIGIN

Heart 2010;96:974-8

Spatial resolution and blooming major weaknesses of CTA

- Blooming makes the calcified lesions look worse then they really are



Cardiac CT-Weaknesses

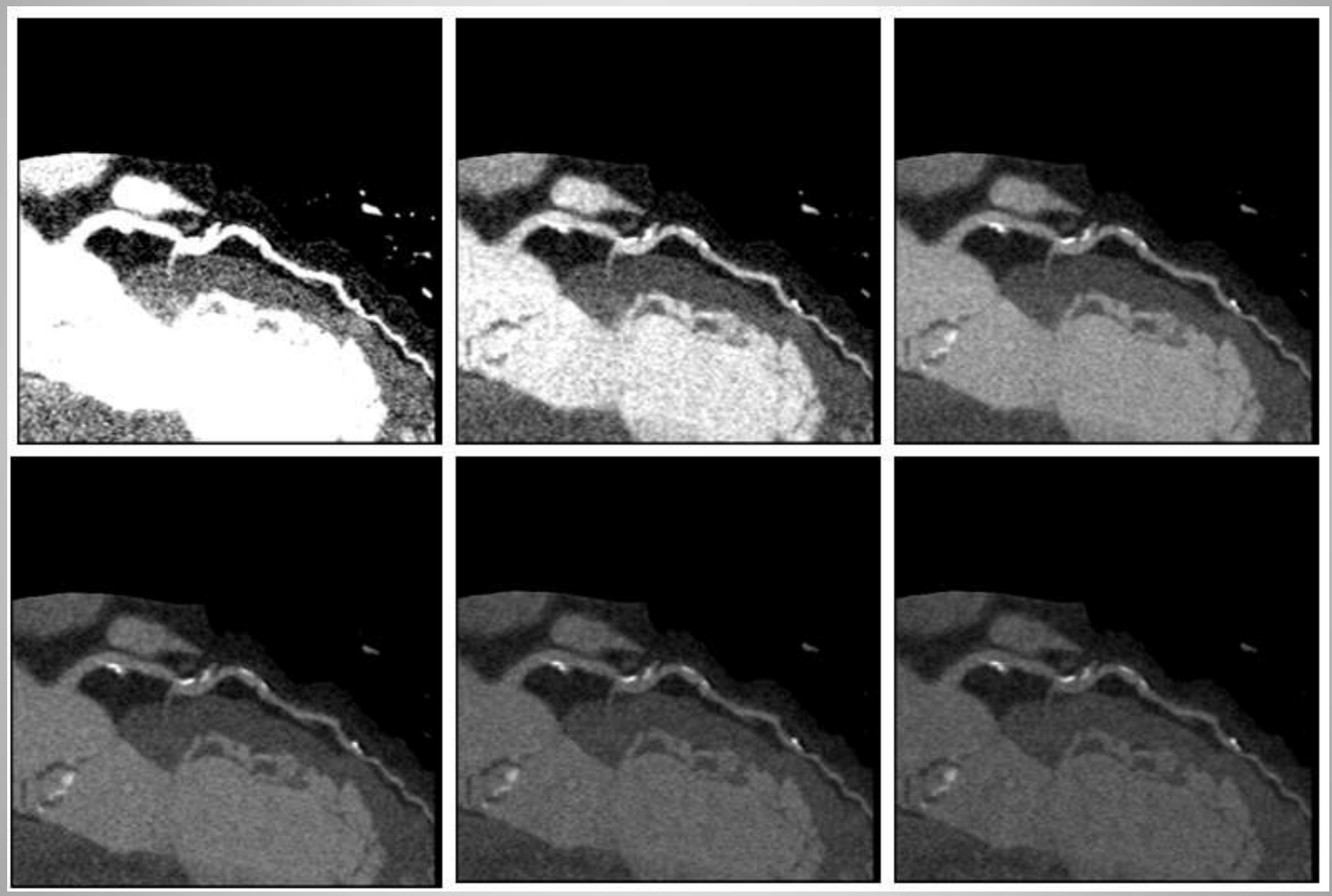
- It overcalls disease
- It is an anatomical test. That is, it demonstrates stenosis but does not tell us if that is causing myocardial ischaemia

GSI

- Rapid switch high and low kVp 0.25msec
- Full FoV (cp Siemens)
- Single source = less miss registration (cp Siemens)
- Production of monochromatic images from 40 to 140 keV
  - Low keV for contrast conspicuity
  - High keV for reduced calcium blooming

keV imaging

40keV



80keV

100keV

140keV

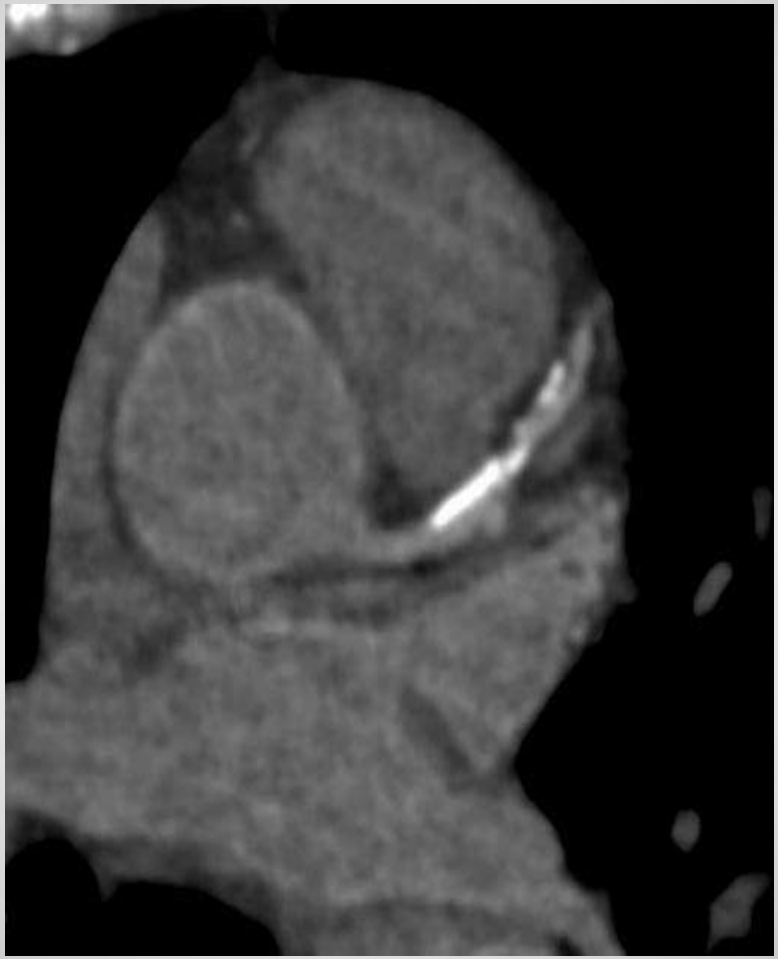
Cardiac GSI: Use of Varying keV to reduce blooming

Changing spectral energies
40keV→ 140keV

Cardiac GSI: calcium subtraction

Material Separation using HAP and Iodine

HAP(Iodine) → Iodine(HAP)

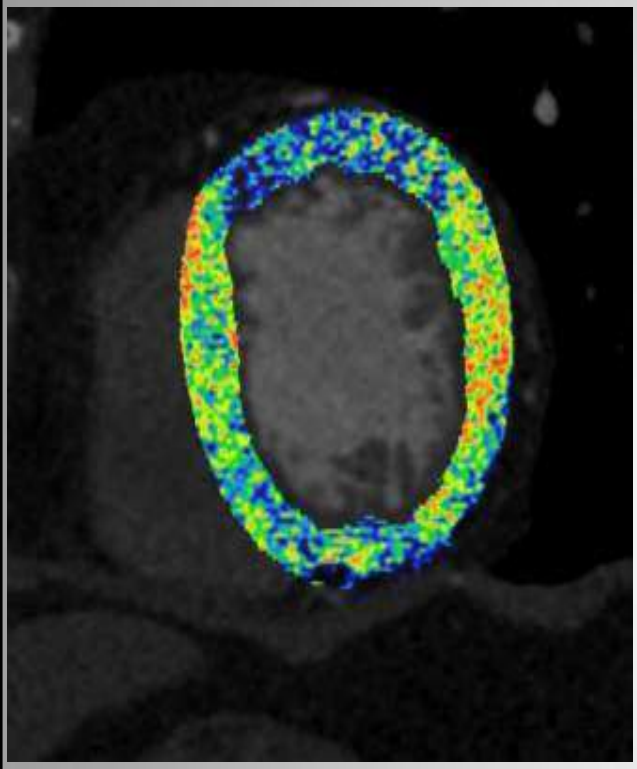


Cardiac GSI Perfusion

- Perform Rest then stress imaging (following adenosine) - look for difference in iodine in myocardium

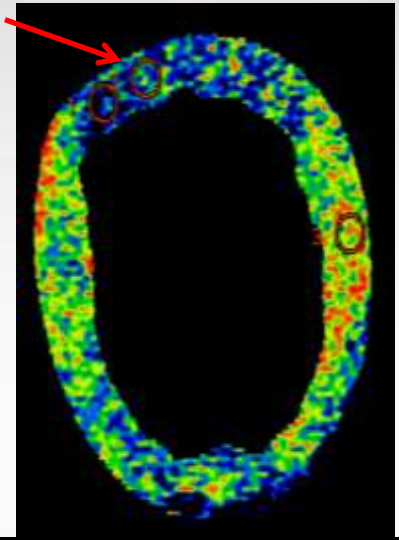
- Need for accurate iodine quantification
- Need to avoid beam hardening

GSI Cardiac; Perfusion

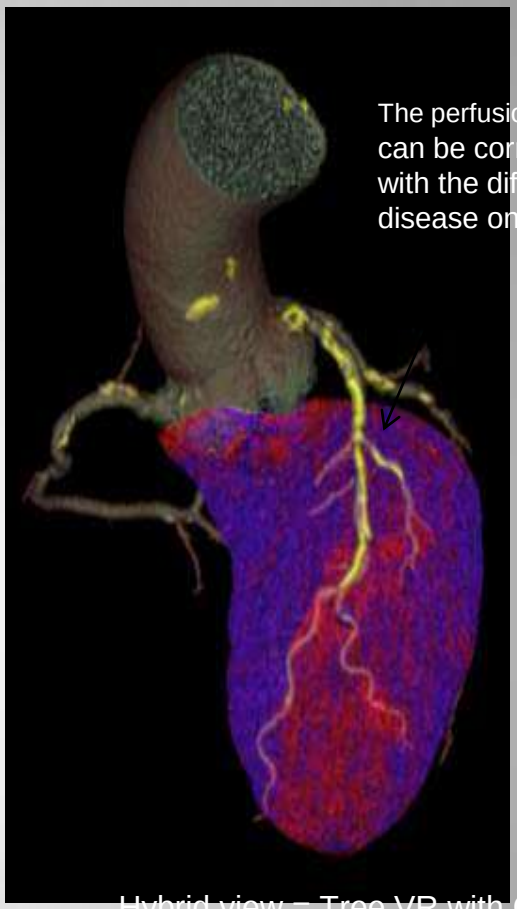


Overlay of GSI Iodine myocardium mask on 70kev images

Perfusion defect



Quantification of iodine values (100µg/cm³) in different regions



The perfusion defect can be correlated with the diffused disease on LAD

Hybrid view = Tree VR with GSI Iodine myocardium segmentation

GSI Cardiac provides iodine quantitative measurements for myocardium perfusion

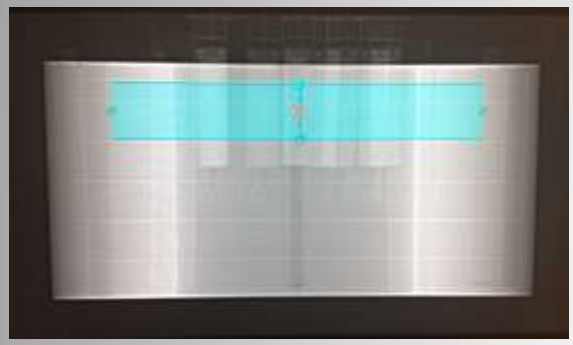
What can we do to test these claims?

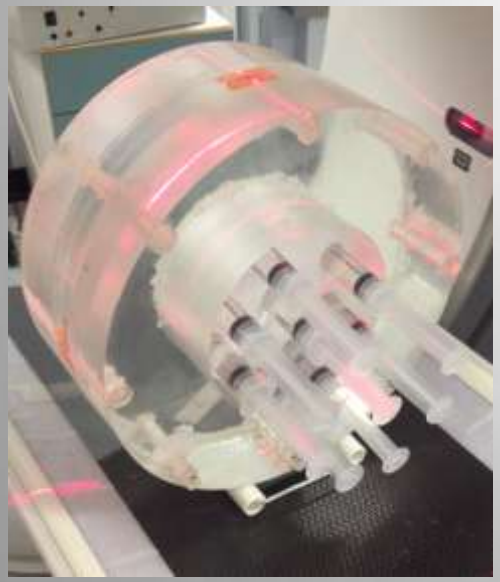
- Need to tailor the tests for the clinical requirements

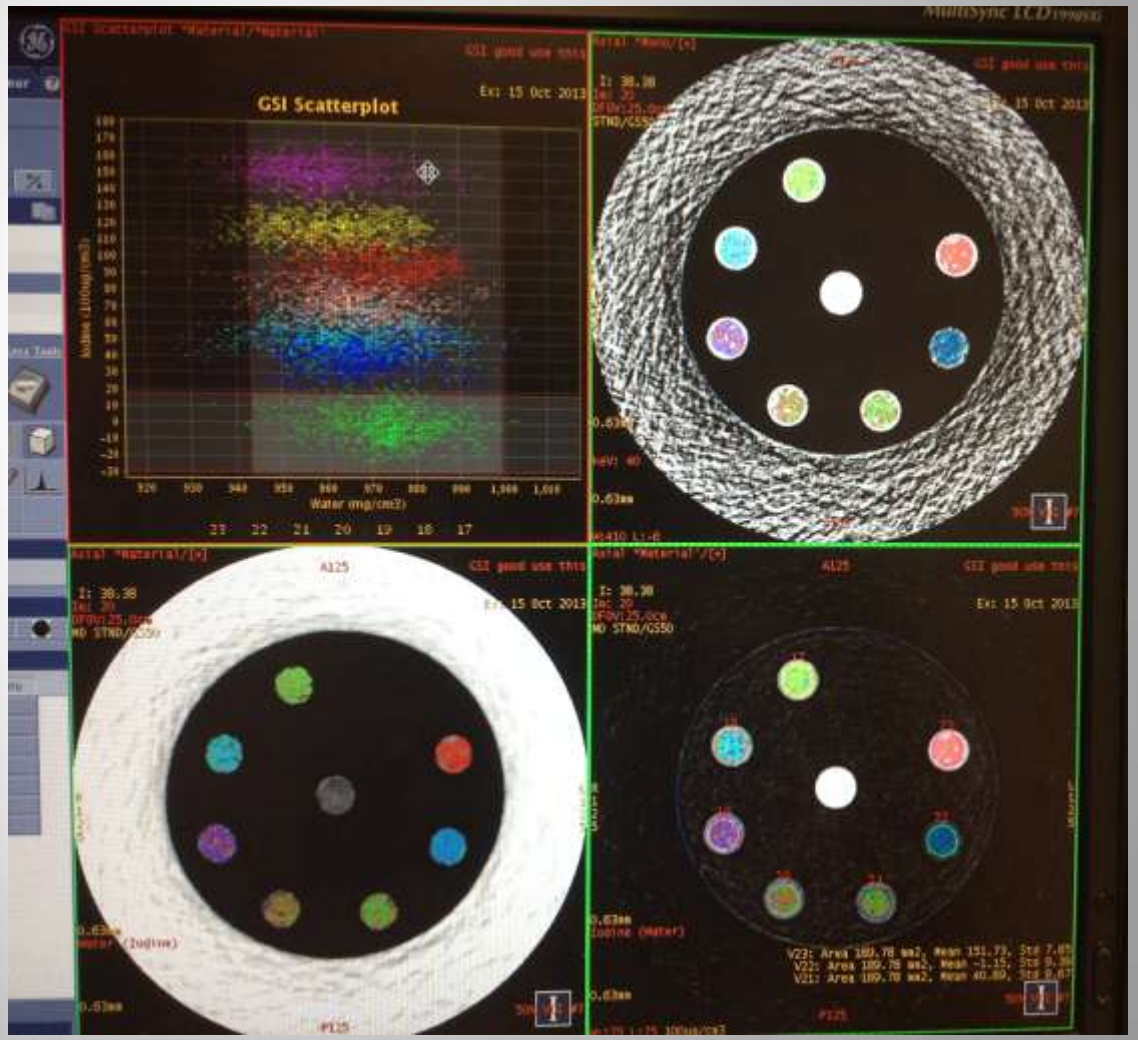
For example……

- Can the scanner accurately determine Iodine/Water concentrations within GSI?
- Does keV imaging add significantly to contrast differentiation?
- Is GSI exempt from beam hardening artefacts?
- How does GSI compare to conventional KVp imaging?

Back to basics

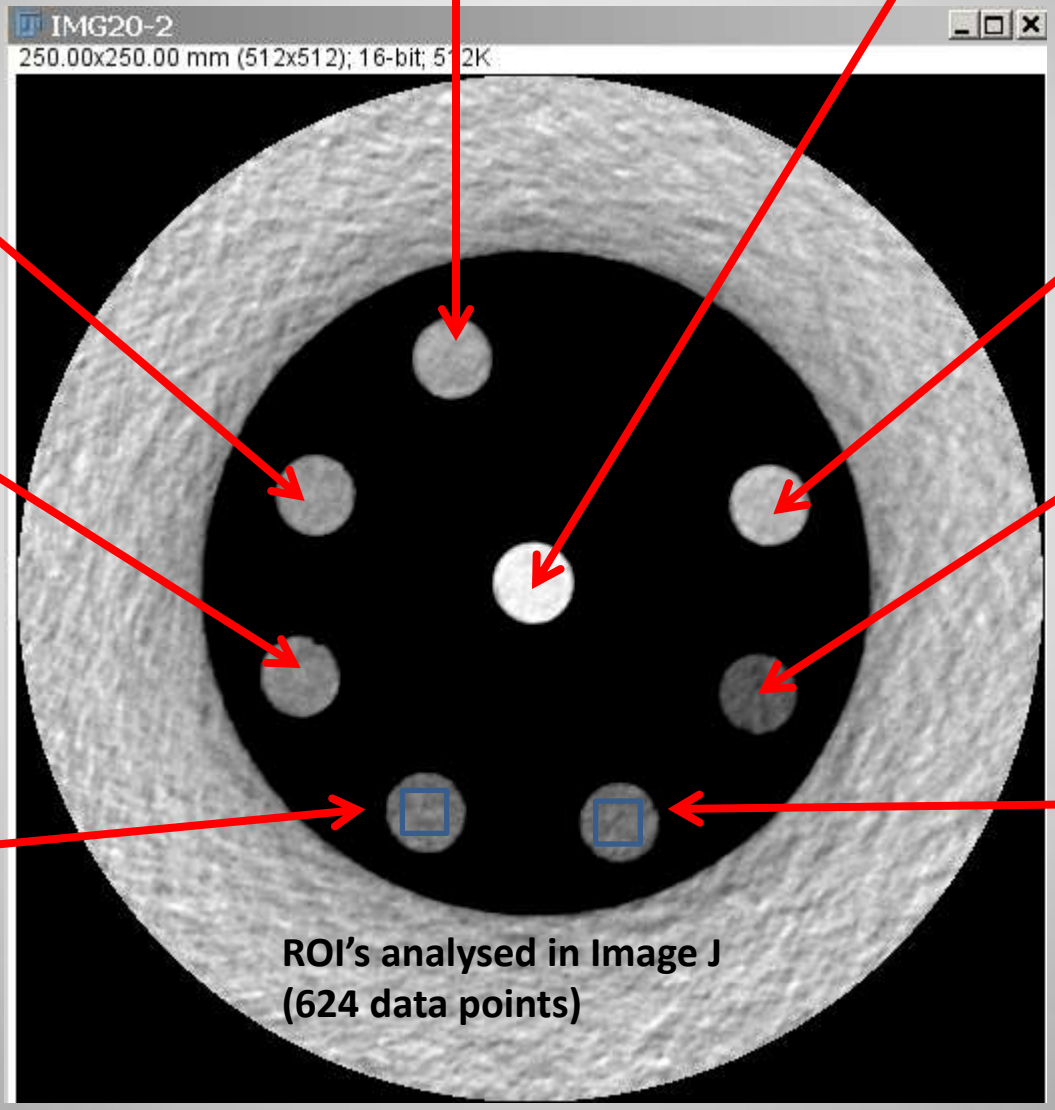




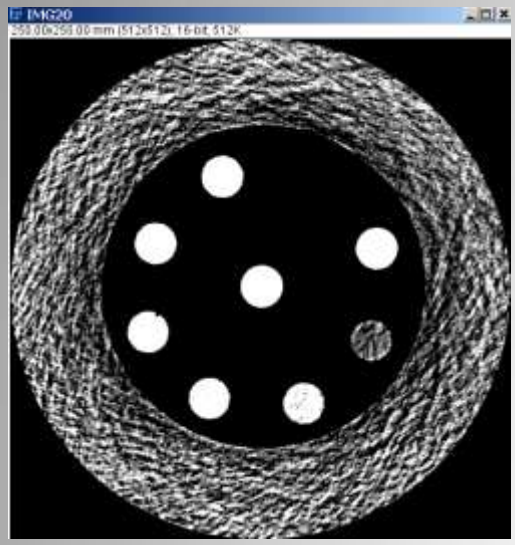


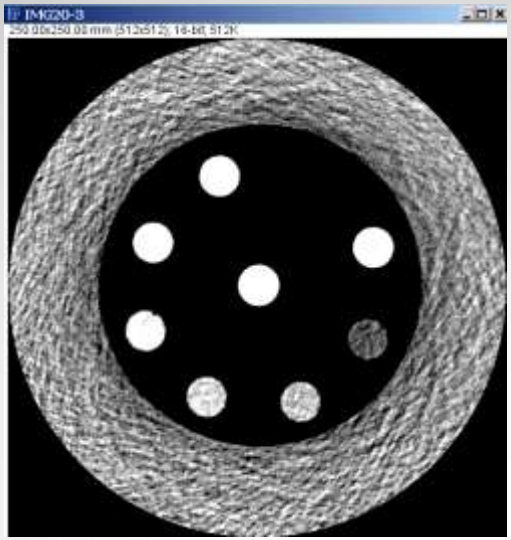
The Phantom

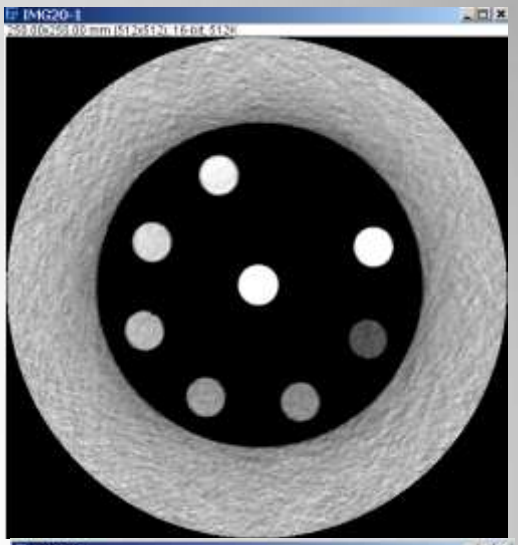
% Iopromide by mass



keV imaging





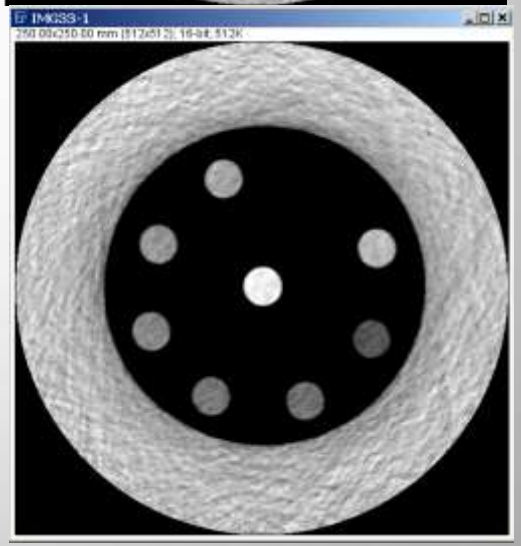


40keV

55keV

75keV

100keV



Zoom in on energy range: (must be between 0.001 - 100000 MeV)

Note: If all data are not displayed in the graph, modify the energy range to view graphed data in the region of interest.
Energy range must cover at least one factor of ten (e.g., 100 to 1000 MeV).

Minimum: 0.001 MeV Maximum: 100000 MeV

Change Energy Range

Constituents (Atomic Number : Fraction by Weight)

```
Z=1     : 0.110544
Z=8     : 0.877356
Z=53    : 0.012100
```

To download data in spreadsheet (array) form, choose a delimiter and use the checkboxes in the table heading. After downloading, save the output by u
`Save As` feature.

Delimiter:

- (•) space
- ( ) | (vertical bar)
- ( ) tab
- ( ) newline

Download data Reset

Edge	(required) Photon Energy	Scattering		☐ Photoelectric Absorption	Pair Production		Total Attenuation	
		☐ Coherent	☐ Incoherent		☐ In Nuclear Field	☐ In Electron Field	☐ With Coherent Scattering	☐ Without Coherent Scattering
	MeV	cm^2/g	cm^2/g	cm^2/g	cm^2/g	cm^2/g	cm^2/g	cm^2/g
	5.500E-02	1.970E-02	1.779E-01	1.304E-01	0.000E+00	0.000E+00	3.280E-01	3.083E-01
	7.000E-02	1.276E-02	1.727E-01	6.579E-02	0.000E+00	0.000E+00	2.512E-01	2.384E-01
	1.400E-01	3.475E-03	1.496E-01	8.893E-03	0.000E+00	0.000E+00	1.619E-01	1.585E-01

Return to selection page.

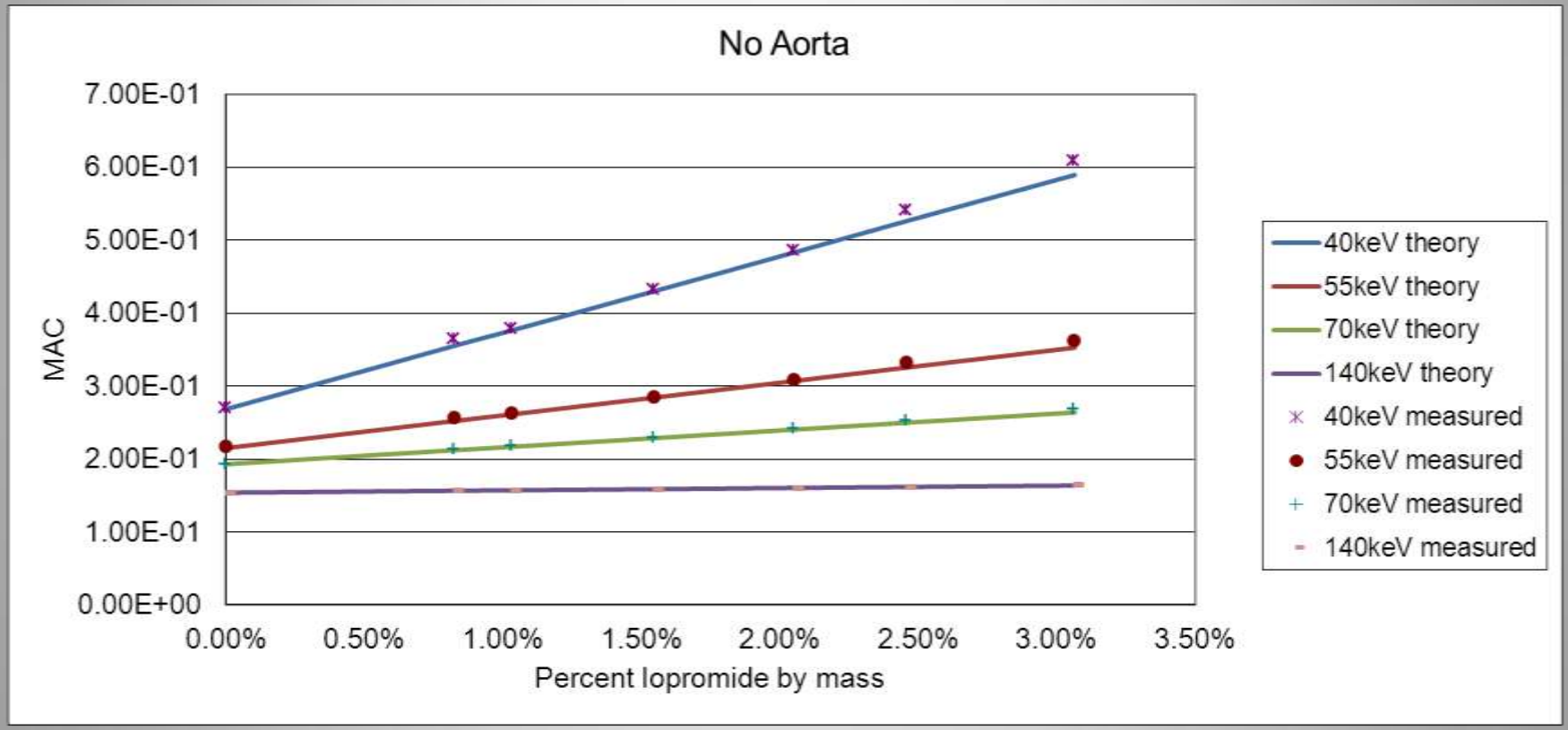
17558		With Aorta						MAC from know Iopromide/H2O cnc		
Sample	Volume Of Solution	Volume Of water	Mass of water/ml	Mass of iopromide/ml	Percentage Iopromide by mass	Percentage Water by mass	Mass attenuation coefficient at 40keV (cm/g)	Mass attenuation coefficient at 55keV (cm/g)	Mass attenuation coefficient at 70keV (cm/g)	Mass attenuation coefficient at 140keV (cm/g)
1	0	30	1000	0	0.00%	100.00%		2.15E-01	1.93E-01	1.54E-01
2	0.4	29.6	996.053333	8.306666667	0.83%	99.17%		2.52E-01	2.12E-01	1.57E-01
3	0.5	29.5	995.066667	10.38333333	1.03%	98.97%		2.61E-01	2.17E-01	1.57E-01
4	0.75	29.25	992.6	15.575	1.54%	98.46%		2.84E-01	2.29E-01	1.59E-01
5	1	29	990.133333	20.76666667	2.05%	97.95%		3.07E-01	2.40E-01	1.60E-01
6	1.2	28.8	988.16	24.92	2.46%	97.54%		3.25E-01	2.50E-01	1.62E-01
7	1.5	28.5	985.2	31.15	3.06%	96.94%		3.53E-01	2.64E-01	1.64E-01
8	2.4	27.6	976.32	49.84	4.86%	95.14%		4.33E-01	3.05E-01	1.69E-01

NIST CALCULATED MAC FROM KNOWN IOPROMIDE/WATER RATIOS

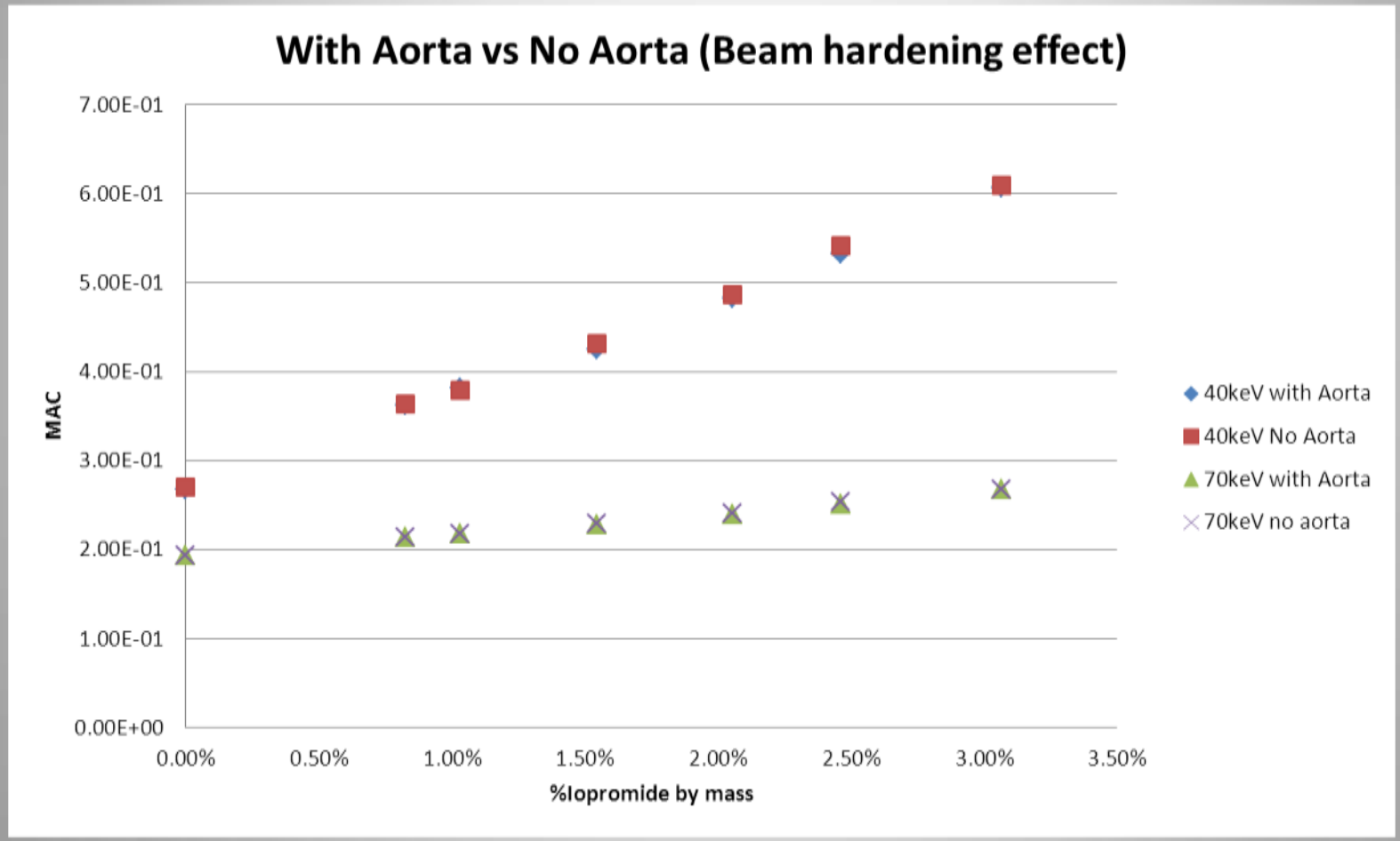
NIST CALCULATED MAC FROM SCANNER DETERMINED IODINE/WATER RATIOS

			MAC from scanner measured I/H2O cnc		
percentage iodine by mass	percentage water by mass	Mass attenuation coefficient at 40keV (cm/g)	Mass attenuation coefficient at 55keV (cm/g)	Mass attenuation coefficient at 70keV (cm/g)	Mass attenuation coefficient at 140keV (cm/g)
0.00%	99.99%	2.68E-01	2.15E-01	1.93E-01	1.54E-01
0.43%	99.57%	3.62E-01	2.55E-01	2.14E-01	1.57E-01
0.52%	98.08%	3.82E-01	2.64E-01	2.18E-01	1.57E-01
0.72%	99.28%	4.26E-01	2.82E-01	2.28E-01	1.59E-01
0.98%	99.03%	4.82E-01	3.07E-01	2.40E-01	1.60E-01
1.21%	98.80%	5.32E-01	3.28E-01	2.51E-01	1.62E-01
1.55%	98.48%	6.07E-01	3.60E-01	2.68E-01	1.64E-01
2.48%	97.55%	8.10E-01	4.47E-01	3.13E-01	1.71E-01

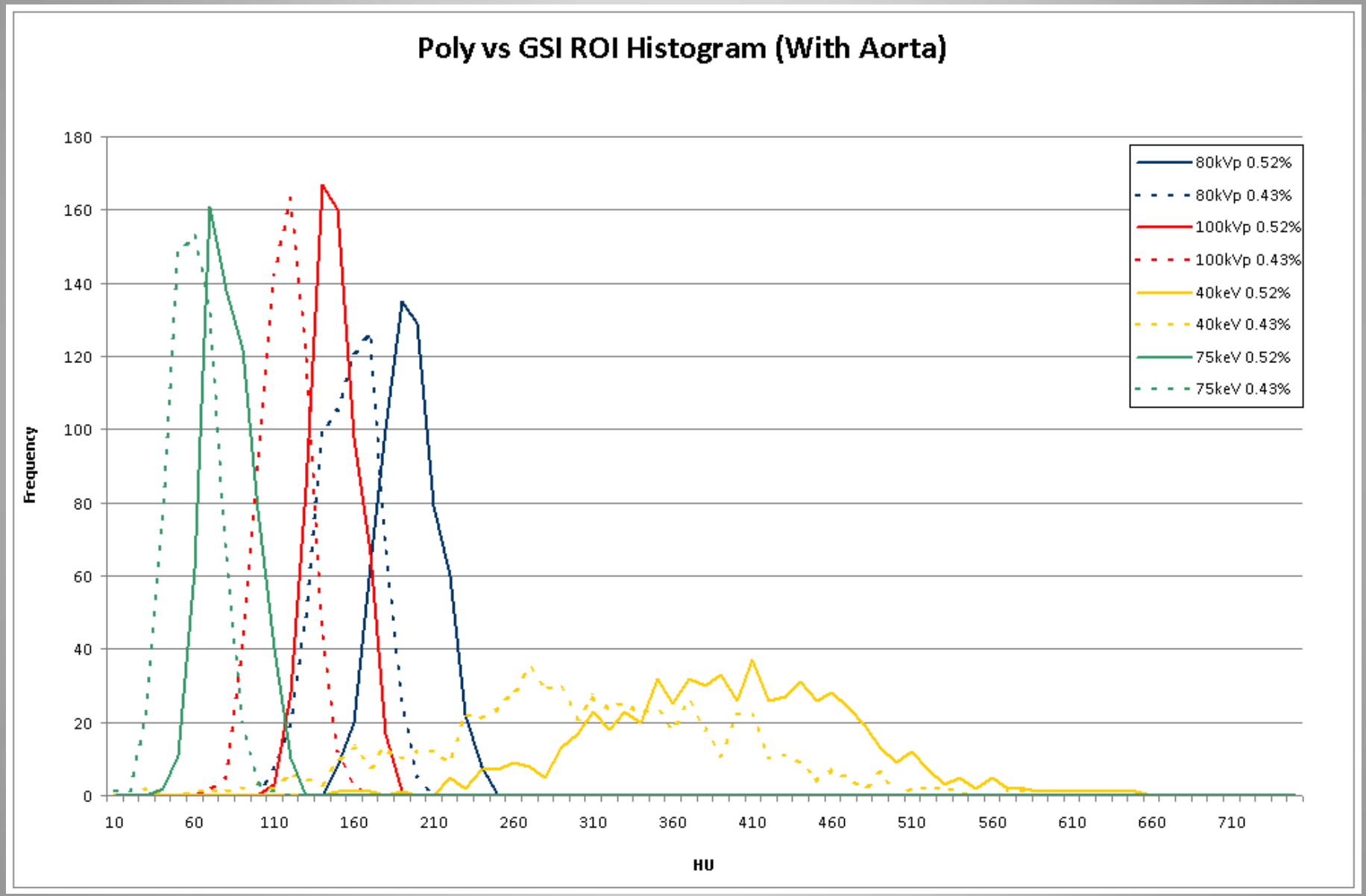
Not Bad!


No Aorta
7.00E-01
6.00E-01
5.00E-01
4.00E-01
3.00E-01
2.00E-01
1.00E-01
0.00E+00
MAC
0.00%
0.50%
1.00%
1.50%
2.00%
2.50%
3.00%
3.50%
Percent Iopromide by mass
40keV theory
55keV theory
70keV theory
140keV theory
40keV measured
55keV measured
70keV measured
140keV measured

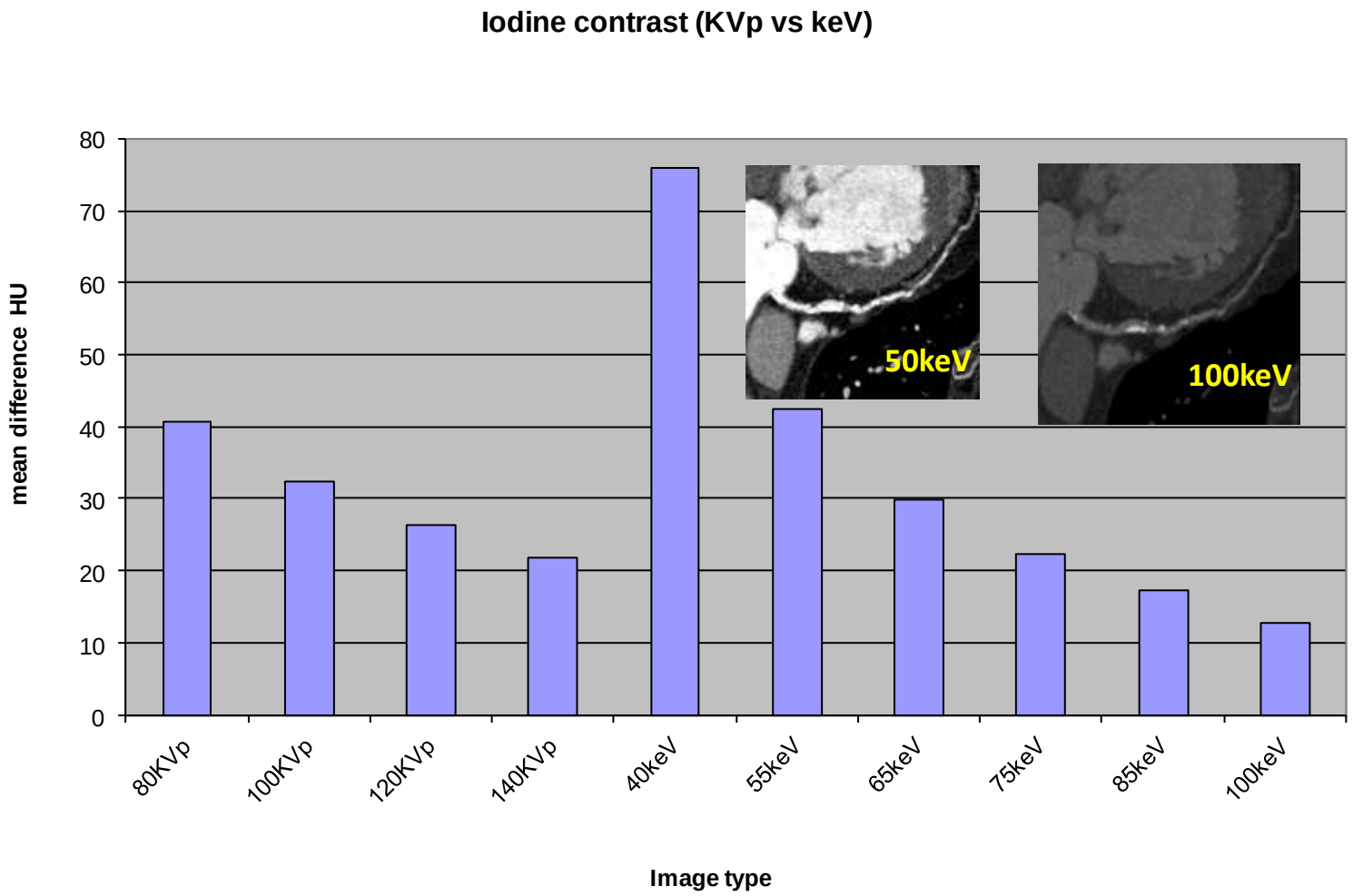
Effect of Beam hardening on GSI calculated MAC



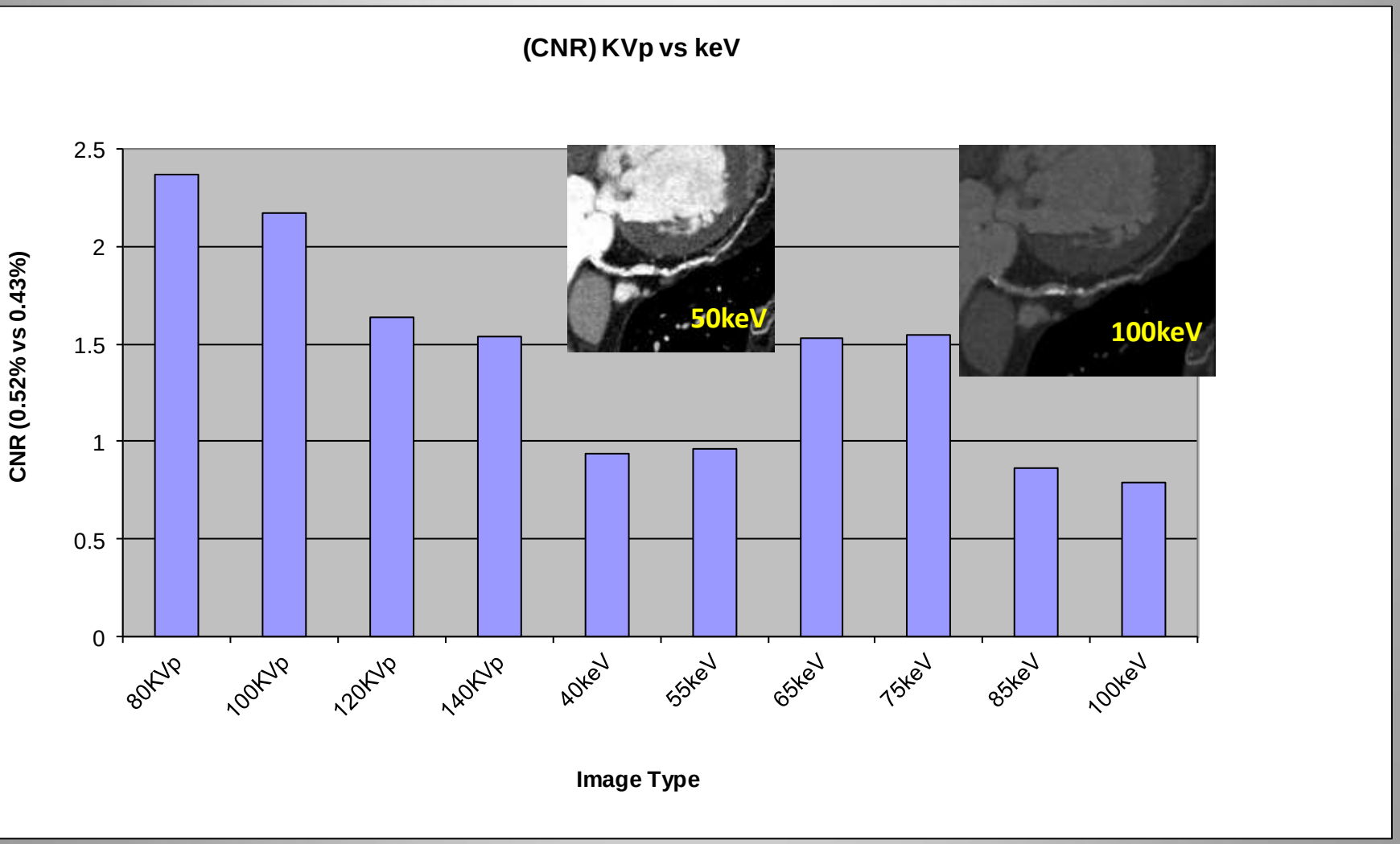
So…. GSI or Conventional Polychromatic imaging (which is better?)



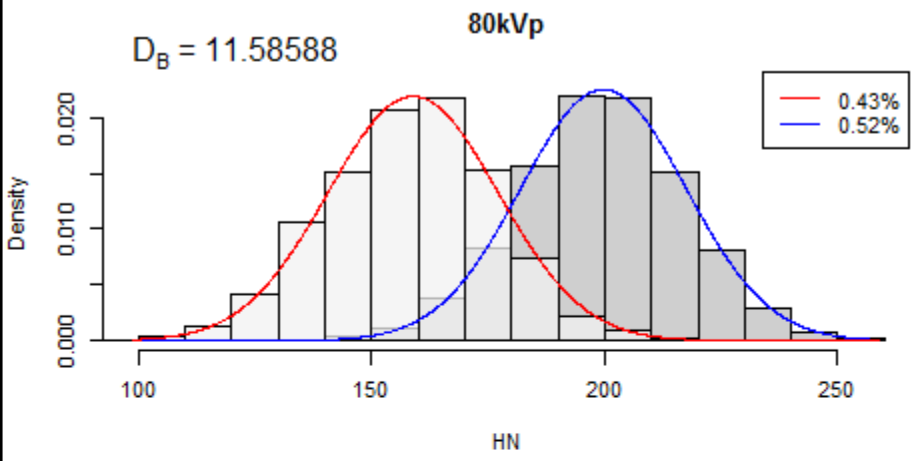
Contrast

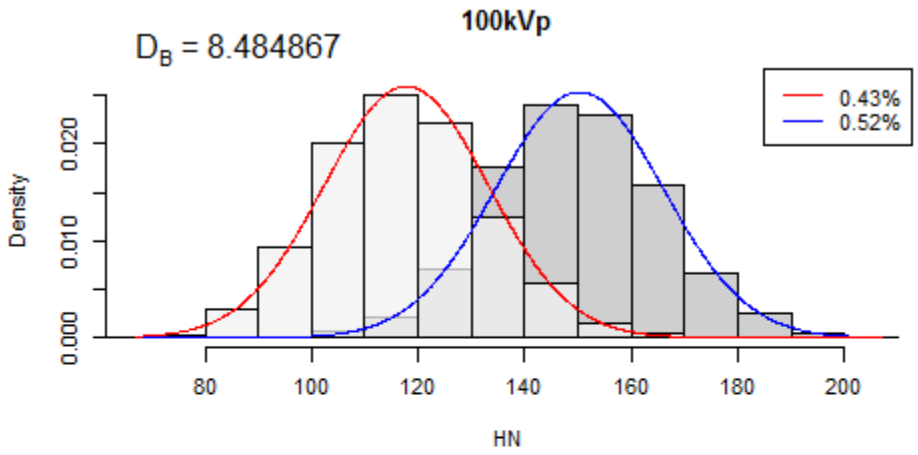

Iodine contrast (KVp vs keV)
mean difference HU
80
70
60
50
40
30
20
10
0
50keV
100keV
80KVp
100KVp
120KVp
140KVp
40keV
55keV
65keV
75keV
85keV
100keV
Image type

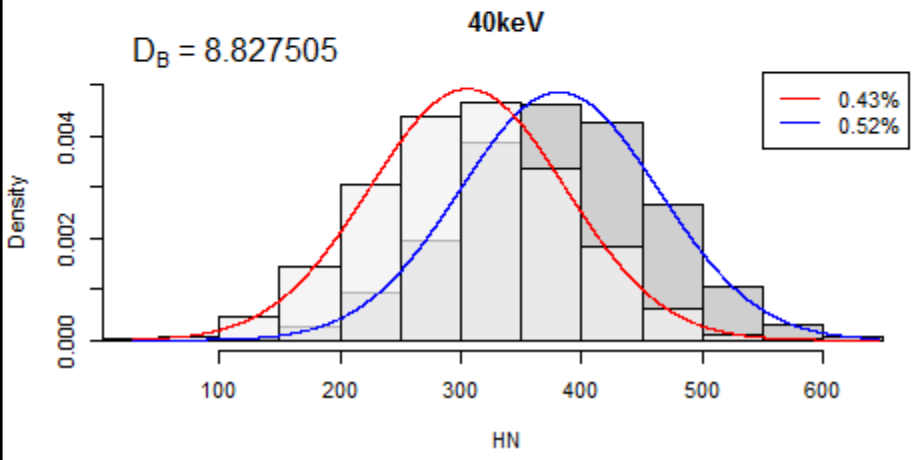
Contrast to Noise Ratio

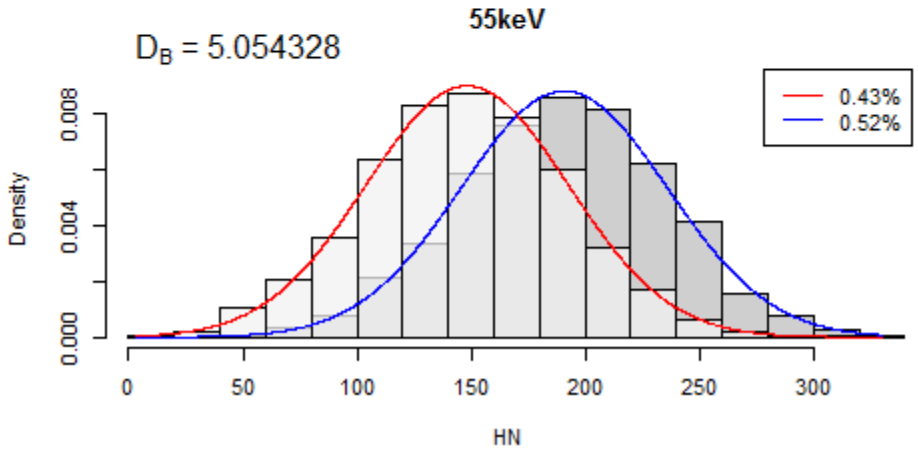


Statistical Analysis

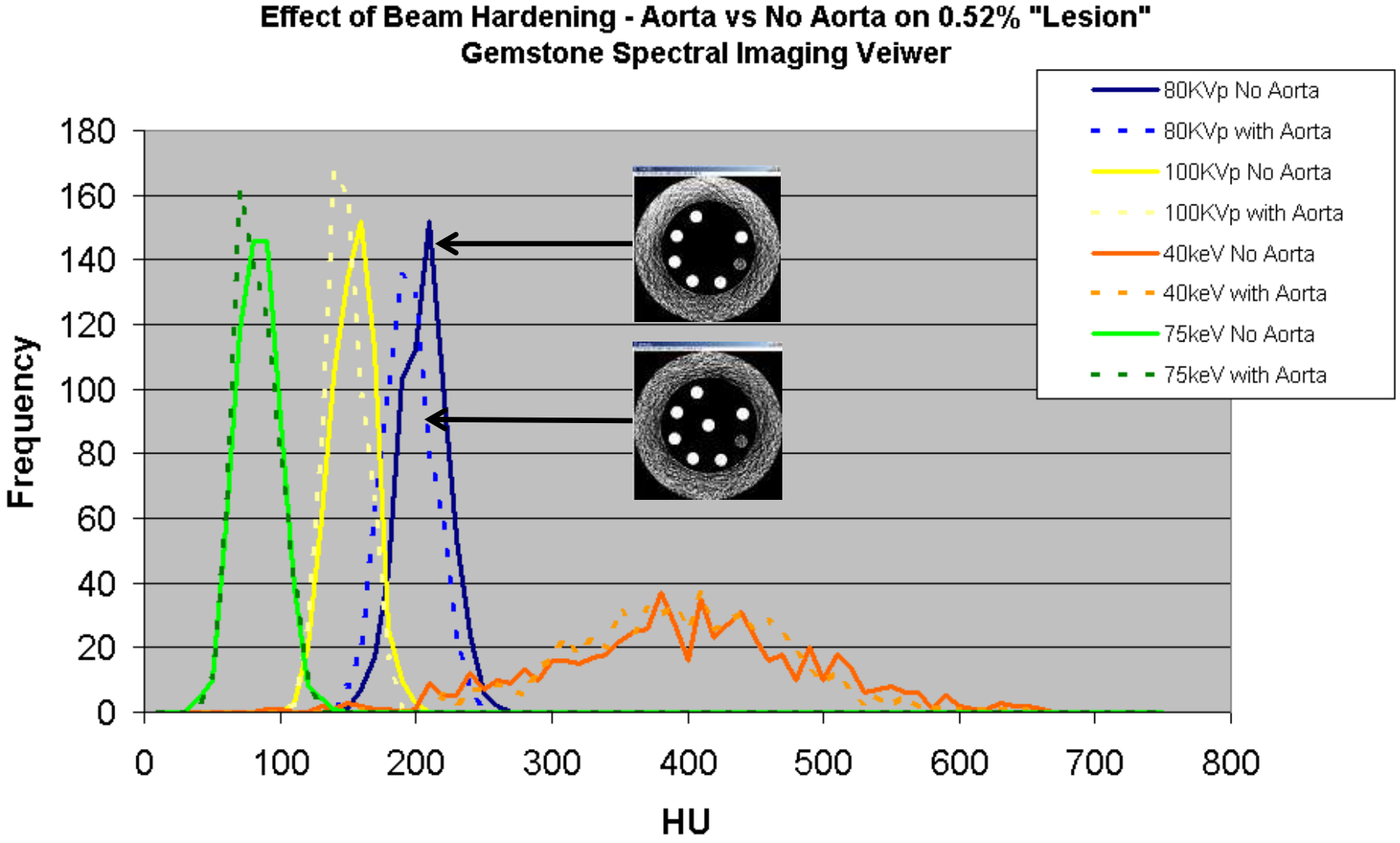








Bhattacharyya distance test


Effect of Beam Hardening - Aorta vs No Aorta on 0.52% "Lesion"
Gemstone Spectral Imaging Veiwer
80KVp No Aorta
80KVp with Aorta
100KVp No Aorta
100KVp with Aorta
40keV No Aorta
40keV with Aorta
75keV No Aorta
75keV with Aorta
Frequency
HU
0
20
40
60
80
100
120
140
160
180
0
100
200
300
400
500
600
700
800

Preliminary Discussion

- Gemstone spectral imaging (GSI) accurately quantifies water/iodine mixtures within this phantom.
- GSI appears to be free from the effects of beam hardening when assessed in this specific phantom.
- Low keV monoenergetic images allow significant increases in contrast, however at reduced CNR when compared to conventional polychromatic imaging.
- The Bhattacharyya distance test was used to compare the separating of two ROI's of 0.52 and 0.48% iodine contrast but the use of this test needs further scrutiny prior to making conclusions.
- Further clinical studies are required to validate the use of Cardiac GSI for calcium subtraction and perfusion imaging.

Questions