Noise & HU Measurements during routine level B QA: Comparison of data with recommended tolerances

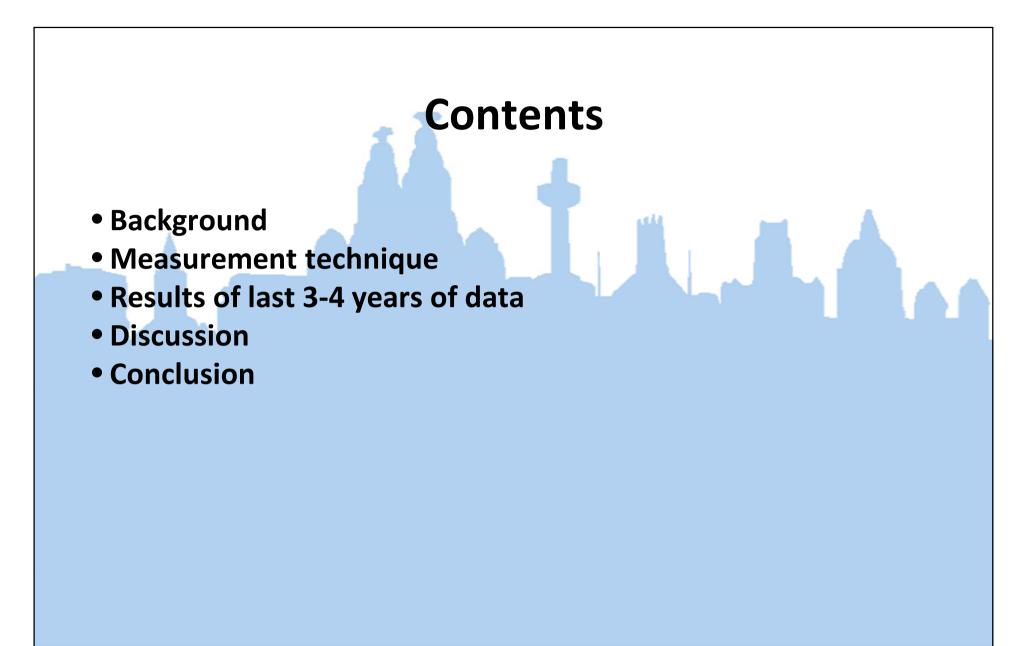
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Paul Charnock – Clinical Scientist, IRS ltd

CT Users Group Meeting, St Mary's Conference Centre, Sheffield. Oct 2011







Background

Early 2010, CTUG topics included

"Inter-slice variation of noise..." "CT number inaccuracy"

There were mentions of measurements failing the IPEM tolerance



Background

In response...

CTUG 2011

• Collated about 2 yrs worth of noise & CT number data by manufacturer for use as alternative baseline to commissioning

1	Scanner b	ased:	-	-	-	•				•		_			-		_
2			Water	Air	Blood	Bone											
3	Average																
4		Data is I	from surv	veys be	etween:			01/04/	/2008	&	01/09/	2010					
5		<u>ge all</u>						Philips A	JII					Marconi			
6		S	Water	Air	Blood	Bone	SD	S	Water	Air	Blood	Bone	SD	S	Water	Air	Blood
-7	Average	0.287%	1.341	-985	122.7	1467	2.83	0.257%	1.457	-998	133.81	1362	2.57	0.443%	1.66	-991.7	124.
8		0.185%	0.76	-982.9	121.2	1444.9	1.82	0.270%	3.4	-994.8	129.1	1318	2.7	0.523%	0.22	-990.25	
				-976.2	122.5		1.58		3.2				3	0.362%	3.1	-993.1	1
				-990.3	123.74		3.13		-4.5								
									-1.1								
			3					0.180%	9.4	-989.2	146.7	1380	1.8				
				-977.1													
22			2.58														
	3 4 5 6 7	2 3 Average 4 5 6 7 Average 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22	3 Average 4 Data is I 5 GE_AII 6 S 7 Average 0.287% 8 0.185% 0.162% 9 0.162% 0.316% 10 0.316% 0.210% 12 0.249% 0.309% 13 0.223% 0.232% 16 0.242% 17 18 0.392% 20 20 0.296% 21 22 0.212% 0.212%	SD Water Average Data is from survers 4 Data is from survers 5 GE All 6 S Water 7 Average 0.287% 1.341 8 0.185% 0.76 9 0.162% -0.31 10 0.210% 1.37 12 0.249% 2.48 13 0.223% 2.73 14 0.309% 3 15 0.242% 1.6 17 0.362% 1.5 18 0.217% 1.1 19 0.392% 1.4 20 0.249% 0.71 21 0.649% 0.16 22 0.212% 2.58	SD Water Air 3 Average Data is from surveys be 4 Data is from surveys be 5 GE All S 6 S Water Air 7 Average 0.287% 1.341 -985 9 0.185% 0.76 -982.9 9 0.162% -0.3 -976.2 10 0.210% 1.37 -992.6 12 0.249% 2.48 -985.2 13 0.223% 2.73 -983.3 15 0.232% 2.5 -978 16 0.242% 1.6 -985.7 17 0.362% 1.5 -984.4 18 0.217% 1.1 -989.6 19 0.392% 1.4 -989.2 20 0.296% 0.71 -989.8 21 0.649% -0.16 -977.1 22 0.212% 2.58 -987.4	SD Water Air Blood 3 Average Data is from surveys between: 4 Data is from surveys between: 5 GE All 6 S Water Air Blood 7 Average GE All -985 122.7 8 0.185% 0.76 -982.9 121.2 9 0.162% -0.3 -976.2 122.5 10 0.210% 1.37 -992.6 122.22 12 0.249% 2.48 -986.2 125.04 13 0.223% 2.73 -983.7 120.44 14 0.309% 3 -993.3 126.5 15 0.242% 1.6 -985.7 122.3 16 0.242% 1.6 -985.7 122.3 17 0.362% 1.5 -984.4 125.2 18 0.217% 1.1 -989.6 123.5 19 0.392% 1.4 -989.2 1	SD Water Air Blood Bone 3 Average Data is from surveys between: 5 5 S Water Air Blood Bone 5 S Water Air Blood Bone 6 S Water Air Blood Bone 7 Average S Water Air Blood Bone 9 0.185% 0.76 -982.9 121.2 1444.9 9 0.185% -0.11 -990.3 123.74 1370.3 10 0.210% 1.37 -992.6 122.22 1493.8 12 0.249% 2.48 -986.2 125.04 1476.3 13 0.223% 2.73 -983.7 120.44 1481.2 14 0.309% 3 -993.3 126.5 1515 15 0.242% 1.6 -985.7 122.3 1472.2 17 0.362% 1.5 -98	SD Water Air Blood Bone Average Data is from surveys between: 5 5 GE All 5 6 S Water Air Blood Bone SD 7 Average GE All 5 GE All 5<	SD Water Air Blood Bone 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Background

Since then... not much

• Recently the topic has been revived with more instances of tolerance failure

• Used as an exercise for review of QA protocol





WHAT ARE WE MEASURING?

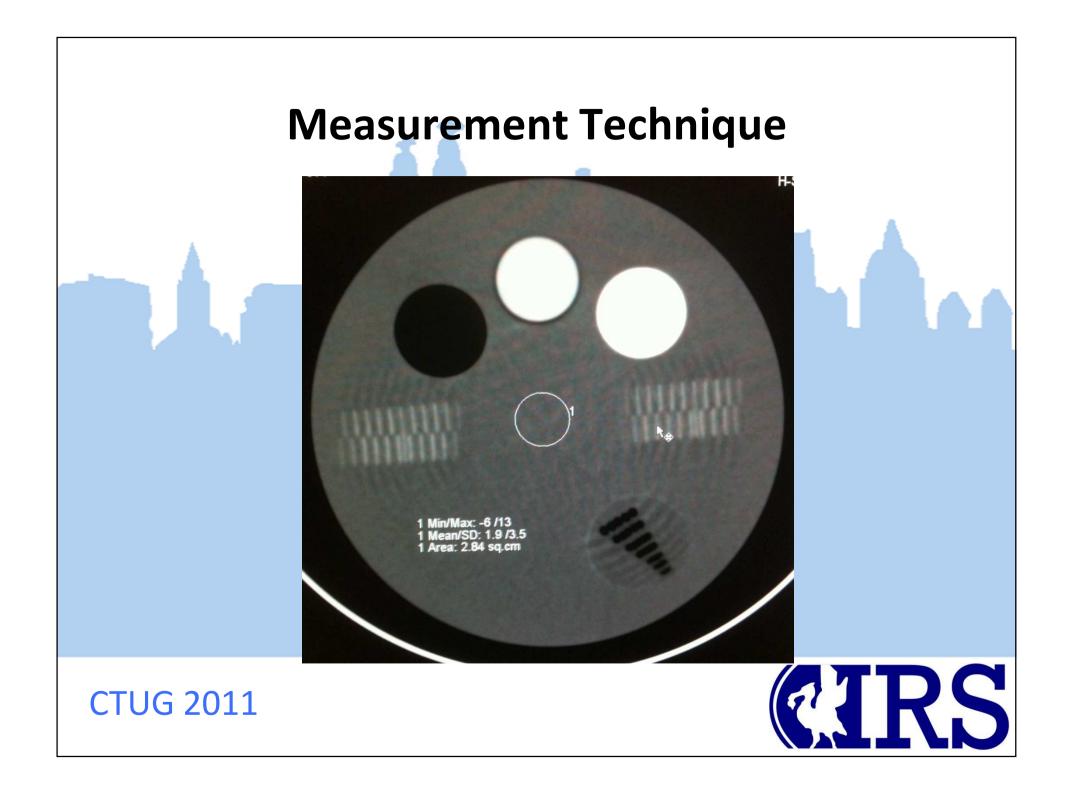
- Noise
- CT Number

Gammex RMI Economy CT Phantom 463

Acrylic & Cortical Bone







SCAN PARAMETERS

Historically:

• Single axial slice, 10 – 12 mm @ 120 kV_p / 400 mAs

Latest protocol added:

- Outer slices for multi slice scan
- Repeatability
- Noise with varying mAs



NOISE

CTUG 2011

- Standard Deviation from a ROI of about 40% (or 1/5 to 1/10) of the feature size
- Normalised using:

S = σ_{water} / (CT_{water} – CT_{air}) x 100%

- IPEM 91 (CT06): Baseline ±10%, 25%
- Historically, σ for air, water, acrylic & bone were collected



CT NUMBER

- Mean from a ROI of about 40% (or 1/5 to 1/10) of the feature size
- IPEM 91 (CT07): Baseline ±5, ±20 Water ±10, ±30 Other Materials

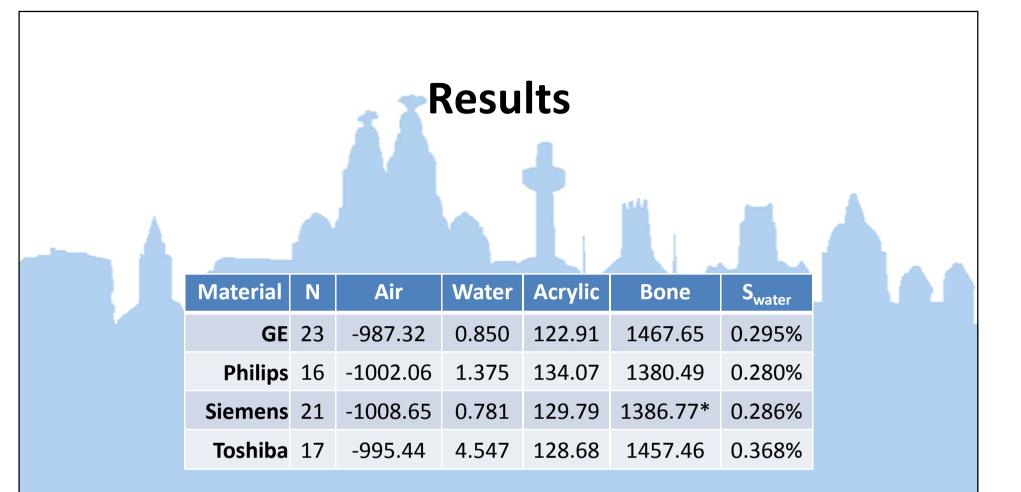




Results										
Material	Air	Water	Acrylic	Bone						
Data points	80	80	80	74*						
Expected CT No.	-1000	0	≈125	≈1350						
Mean CT No.	-997.7	1.76	128.3	1421.4						
Max , Min (Range)	-963 <i>,</i> -1032 (68.8)	9.4 <i>,</i> -5.5 (14.9)	146.7 <i>,</i> 119.8 (26.9)	1538* <i>,</i> 1198 (340)						
Mean S		0.311%								

*6 Bone values were removed from the data as it was suspected they were taken using wrong technique





*6 Bone values were removed from the data as it was suspected they were taken using wrong technique These S values are comparable to published data from ImPACT



WHY MEASURE NOISE?

- Quantum Noise should be proportional to 1/SQRT(mAs)
- Other noise sources include structural / electronic
- Establish a relationship at baseline, and any deviation could indicate issues such as misalignment, or reconstruction





BASELINE

- Commissioning
 - Affected by kV / mAs / filtration / slice width /...
 - Tube lifetimes average ≈ 3 years, surveys ≈ 2 years...
- General pool
 - T-test scores show that it is likely that different manufacturers data is from different data sets
- Pool of same manufacturer / model





APPLY IPEM TOLERANCE TO BASELINE

•Pool of same manufacturer / model

Manufacturer	Number	Pass	Remedial	Suspension
GE	23	4	10	9
Philips	16	7	6	3
Siemens	20	5	5	10
Toshiba	17	3	7	7
TOTAL	76	19	28	29



WHAT IF ...?

- Noise is outside IPEM suspension levels
 - -25%:
 - does this mean dose is increased?
 - If not, does this mean this system is better?
 - +25%:
 - Are we losing contrast (high / low)
 - Are the exposure factors being increased to compensate (patient dose audit)
 - Are there other problems (alignment / recon / etc)





PURPOSE

- CT Number should be linear for material attenuation with Air = -1000 & Water = 0
- Compare displayed number with expected value Used mean of each manufacturer for acrylic / bone





APPLY IPEM TOLERANCE TO BASELINE

•Pool of same manufacturer / model

Material	Number Pass		Remedial	Suspension	
Air	80	34	44	2	
Water	80	65	15	0	
Acrylic	80	76	6	0	
Bone	74	7	10	57	





APPLY IPEM TOLERANCE TO BASELINE

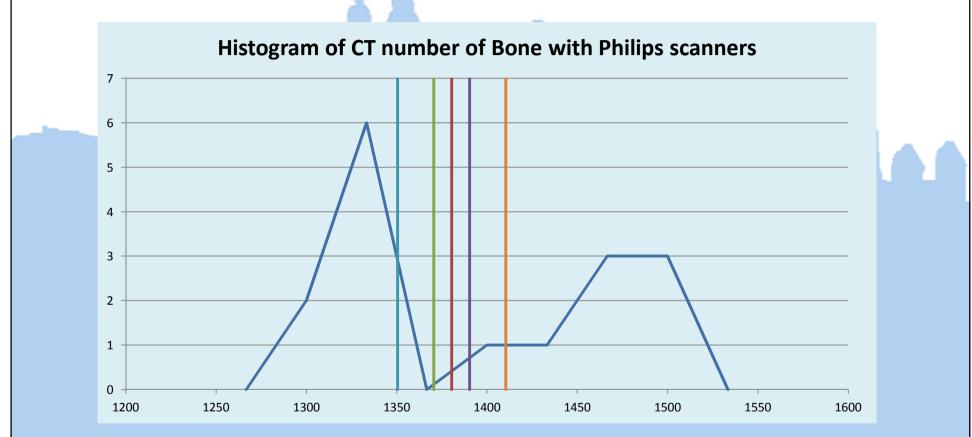
•Pool of same manufacturer / model

CTUG 2011

Material	Number	Pass	Remedial	Suspension	
Air	80	34	44	2	
Water	80	65	15	0	
Acrylic	80	76	6	0	
Bone	74	7	10	57	

Almost all from Philips & Siemens systems





• Different distributions within manufacturer data – tolerance not applicable to mean value



Conclusion - Noise

SUGGESTION

- Tolerance is only applicable to an increase in Noise
- Noise tolerance is an absolute value rather than a percentage
- I don't think I have enough good data to suggest a value

...but if pressed, I would say 0.5% as remedial level for standard head protocol

Possibly tolerances for other types of scanning (hi res, helical, body, ...)



Conclusion – CT Number

SUGGESTION

- Perhaps materials other than Water/Air, CT number variation could be a percentage again, don't feel I have the data to suggest values but perhaps linked to local QA?
- Really need to investigate the implications of being outside tolerance





Summary of thoughts

- Measurements vs Time allowed on scanner
- Are we all recording recon filter?
- What do any of us currently do if noise / CT number is outside tolerance?
- What are the effects of being outside limits?
- Should we change the tolerance limits?
- Is using the pool of manufacturer data for a baseline acceptable?



Acknowledgements

My colleagues for help and assistance in putting this together:

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