

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

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Contents

- **Background**
- **Measurement technique**
- **Results of last 3-4 years of data**
- **Discussion**
- **Conclusion**

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...

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

1	Scanner based:																
2	SD	Water	Air	Blood	Bone												
3	Average																
4	Data is from surveys between: 01/04/2008 & 01/09/2010																
5	GE All						Philips All						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	123
9		0.162%	-0.3	-976.2	122.5	1483.9	1.58	0.302%	3.2	-990.9	136	1319	3	0.362%	3.1	-993.1	1
10		0.316%	-0.11	-990.3	123.74	1370.3	3.13	0.216%	-4.5	-1024	133.3	1435	2.2				
11		0.210%	1.37	-992.6	122.22	1493.8	2.09	0.241%	-1.1	-995.4	124.7	1303	2.4				
12		0.249%	2.48	-986.2	125.04	1476.3	2.46	0.331%	-3.3	-1000	137	1461	3.3				
13		0.223%	2.73	-983.7	120.44	1481.2	2.2	0.261%	3.1	-994.9	129.9	1318	2.6				
14		0.309%	3	-993.3	126.5	1515	3.08	0.180%	9.4	-989.2	146.7	1380	1.8				
15		0.232%	2.5	-978	123.86	1460.7	2.27										
16		0.242%	1.6	-985.7	122.3	1472.2	2.39										
17		0.362%	1.5	-984.4	125.2	1480.1	3.57										
18		0.217%	1.1	-989.6	123.5	1498.2	2.15										
19		0.392%	1.4	-989.2	122.8	1458.5	3.88										
20		0.296%	0.71	-989.8	120.88	1392.1	2.93										
21		0.649%	-0.16	-977.1	119.75	1481.9	6.34										
22		0.212%	2.58	-987.4	122.86	1478.8	2.1										
23		0.277%	0	-981.9	128.2	1485.6	2.7										

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

Measurement Technique

WHAT ARE WE MEASURING?

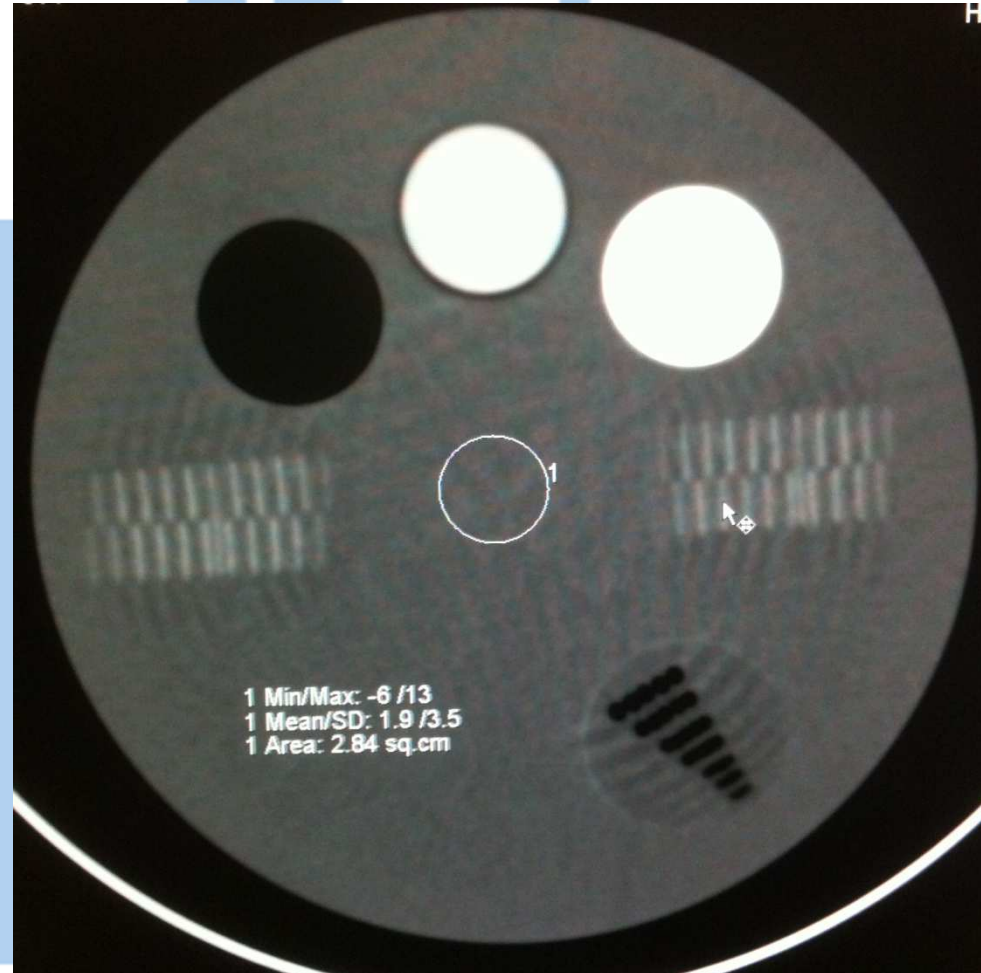
- Noise
- CT Number

Gammex RMI
Economy CT Phantom 463

Acrylic & Cortical Bone



Measurement Technique



Measurement Technique

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

Measurement Technique

NOISE

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

$$S = \sigma_{\text{water}} / (CT_{\text{water}} - CT_{\text{air}}) \times 100\%$$

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

Measurement Technique

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, -1032 (68.8)	9.4, -5.5 (14.9)	146.7, 119.8 (26.9)	1538*, 1198 (340)
Mean S		0.311%		

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

Results

Material	N	Air	Water	Acrylic	Bone	S _{water}
GE	23	-987.32	0.850	122.91	1467.65	0.295%
Philips	16	-1002.06	1.375	134.07	1380.49	0.280%
Siemens	21	-1008.65	0.781	129.79	1386.77*	0.286%
Toshiba	17	-995.44	4.547	128.68	1457.46	0.368%

*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

Discussion - Noise

WHY MEASURE NOISE?

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

Discussion - Noise

BASELINE

- **Commissioning**
 - **Affected by kV / mAs / filtration / slice width / ...**
 - **Tube lifetimes – average \approx 3 years, surveys \approx 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**

Discussion - Noise

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

Discussion - Noise

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)**

Discussion – CT Number

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

Discussion – CT Number

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

Discussion – CT Number

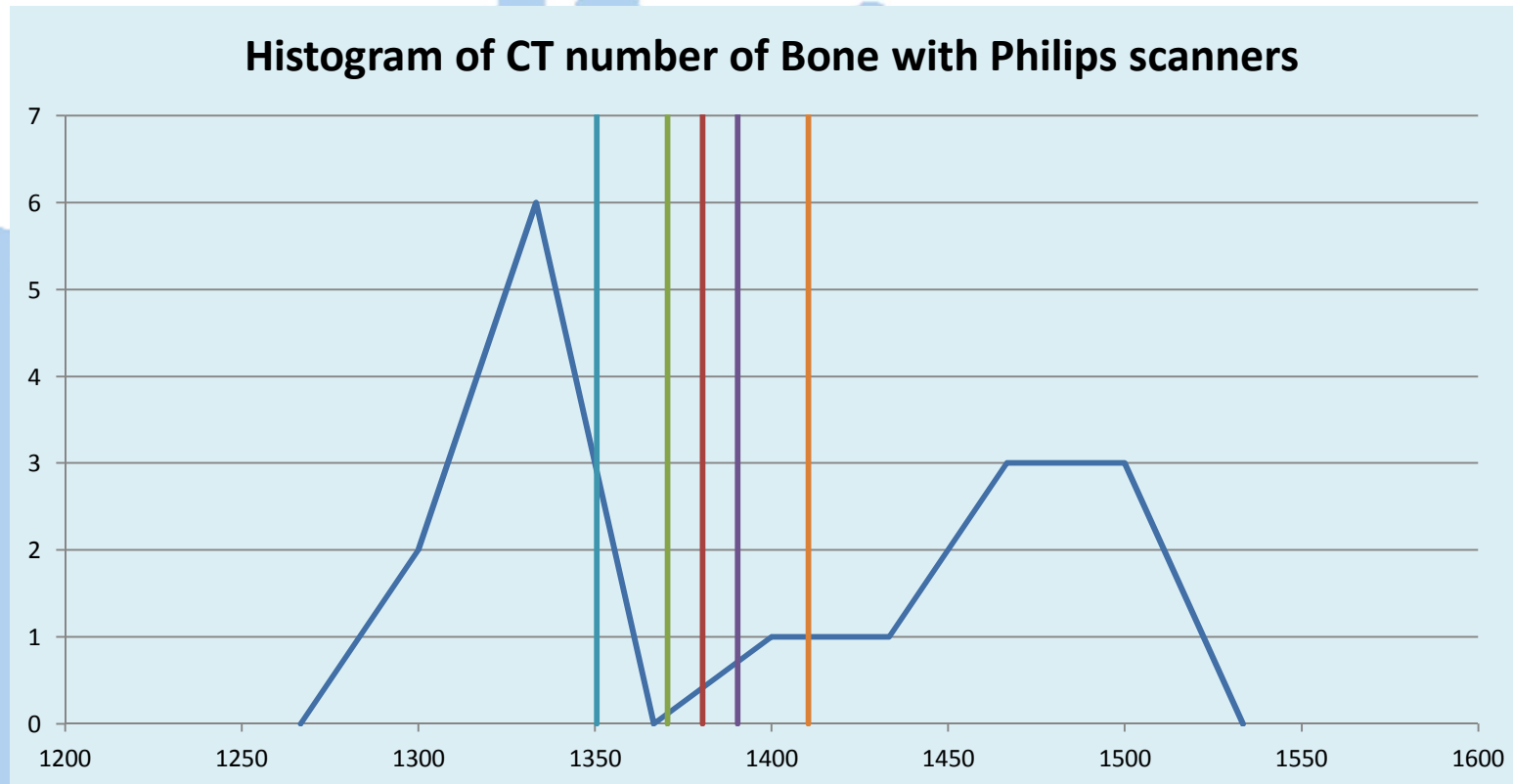
APPLY IPEM TOLERANCE TO BASELINE

- 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

Almost all from Philips
& Siemens systems

Discussion – CT Number



- 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?**

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