AAPM Comments QIBA CT: Lung Densitometry Profile

General Comments (from Coverletter): The implementation from the medical phyusicist and technologist perspective is technically complex and AAPM urges simplification where possible.

1. P17 L1

"Shall demonstrate a slice sensitivity profile with FWHM ≤ 1.0 mm as described in Section 4.1.4." However, this document doesn't contain section 4.1.4.

Response: Thank you for identifying this error. The assessment procedure for the slice sensitivity profile is in Section 4.1.3. The reference to this section has been corrected throughout the document.

2. P17 Table

The measured HU spec for air is likely too strict - especially without additional scattering material. GE scanners especially have difficulty meeting high or low CT # specifications when there is not enough scattering material in the scan).

Commented [SBF1]: Acqusition, Needs Discussion.

Commented [SBF2R1]: See response based on discussion at Jan. 22 meeting.

Response: The choice for the HU specification (-1000 HU ± 6 HU for air within phantom) is based on actual performance ~~across the COPD Gene network~~in a ground work study peformed by the QIBA CT Lung Density Biomarker Committee using the COPD Gene phantom inclusive of ~~more than 10~~3 sites with 4 different CT scanner makes and models ~~included~~(Table A.1). The data from this study clearly show values well within the specification using the standard protocols proposed in Appendix E.~~.~~

	kVp	Mean Lung	Mean Water	Mean Inside Air	Mean Outside Air	Mean Acrylic	Mean Block1	Mean Block2	Mean Block3	Mean Block4	Mean Bloc
SIEMENS Force	80	-858.95	-4.40	-1001.54	-998.64	-221.48	-788.39	-831.24	-699.97	-895.37	-950.13
	90	-858.99	-4.00	-1002.15	-998.92	-210.45	-787.91	-830.48	-698.97	-894.75	-949.91
	100	-858.58	-3.75	-1001.60	-999.02	-202.74	-786.77	-829.31	-698.01	-893.60	-948.93
	110	-858.81	-3.93	-1001.67	-999.23	-197.28	-786.76	-829.36	-697.89	-893.77	-948.91
	120	-858.47	-3.73	-1001.49	-999.11	-192.25	-786.18	-828.79	-697.21	-893.18	-948.48
	130	-858.41	-3.80	-1001.50	-999.11	-188.54	-785.89	-828.46	-696.83	-892.85	-948.20
	140	-858.20	-4.12	-1001.24	-999.09	-185.61	-785.58	-828.10	-696.58	-892.56	-947.99
	150	-858.01	-4.04	-1001.16	-998.90	-182.85	-785.31	-827.80	-696.30	-892.26	-947.75
SIEMENS Edge	80	-856.73	-3.88	-1000.79	-998.30	-218.41	-789.58	-832.13	-700.99	-896.95	-951.31
	100	-854.66	-1.92	-999.29	-999.05	-197.92	-787.05	-829.70	-698.36	-894.65	-949.30
	120	-854.72	-0.63	-999.65	-999.36	-186.53	-786.45	-829.35	-697.47	-894.58	-949.14
	140	-856.32	-0.36	-1001.13	-999.23	-180.26	-786.89	-829.76	-697.51	-895.24	-949.93
GE HD750	100	-853.43	4.01	-999.25	-996.74	-197.09	-782.74	-826.14	-694.67	-890.12	-945.65
	120	-853.89	2.27	-999.61	-996.88	-187.24	-782.63	-826.00	-694.45	-889.80	-945.56
	140	-853.27	1.40	-999.17	-996.58	-180.42	-782.14	-825.39	-693.65	-889.11	-945.05
Philips iCT	80	-862.52	0.98	-1004.65	-999.22	-214.38	-785.54	-829.89	-695.89	-893.04	-948.20
	100	-860.43	3.81	-1003.07	-999.20	-194.44	-783.60	-827.99	-693.53	-891.48	-947.19
	120	-858.80	2.92	-1001.79	-999.41	-183.59	-782.40	-826.84	-692.59	-890.32	-945.97
Average	120	-856.47	0.21	-1000.64	-998.69	-187.40	-784.41	-827.74	-695.43	-891.97	-947.28
StDev	120	2.52	3.04	1.17	1.21	3.60	2.20	1.58	2.33	2.29	1.79
Range	120	4.90	6.65	2.18	2.53	8.66	4.05	3.35	4.88	4.78	3.58

Table A.1: Values for density standards in HU for the COPDGene phantom acquired across 3 sites on 4 different CT scanner makes and models using a standard helical protocol with 40 mm Collimation, 0.625 mm Slice Thickness, 200 mA, Large SFOV, 0.984 Pitch, 0.5 second rotation time, various tube potentials from 80-150 KVp. The values shown are means for 5 consecutive scans acquired and calculated as described in 4.1.1. Here Blocks 1-5 correspond to different foam densities (16, 12, 20, 8 and 4 lb/ft^3, respectively).

To clarify, the specification for inside air bias is expected to be within ± 6 HU of -1000 HU across 5 independent realizations. This is empirically achievable as all of the measures in this multicenter trial were within ± 2.2 HU of -1000 HU for the 120 KVp tube potential.

3. P18 L312

QMP should probably be diagnostic QMP.

Response: Agreed. Changed qualification for the physicist actor to: "Shall be a diagnostic radiology Qualified Medical Physicist (QMP) as defined by AAPM" throughout.

4. P22 Table

Table speed specified earlier in the document is 3 cm/s.

Response: Noted that the reference to 4 cm/s was in error in the table 3.4.2 and corrected to 3 cm/s. Thank you.

5. P24 Table

Scout Scans is vendor specific, recommend using Scan Projection Radiograph.

Response: Done.

6. P26 Table

For CT dose weight based is a poor metric to define expected CTDIvol. Diameter or water equivalent diameter would be better. Or perhaps the "standard" patient defined for lung cancer screening exams could be specified.

Response: Standardizing CTDIvol using water equivalent diameter would be superior but, at present, would require additional off-line calculations that are unlikely to be robustly integrated into a multi-center trial. The role of automated exposure control (AEC) to modulate CT dose for body size and tissue density in the thoracic cavity remains an open issue for quantitative CT. In the present version of the profile w~~We have made a choice to~~ design the ~~profile~~specifications around an average CTDI vol of 3 mGy for a 75kg subject ~~allowing~~with adjustment above or below this value according to the CT scanner manufacturer's calibration for ~~of~~ anatomic~~cal~~ attenuation using their commercial AEC~~automatic exposure control~~. This allows for a conceptually intuitive reference for the low CT dose target of the profile, while allowing adjustment of dose for patient size that can be consistently implemented across a multi-center trial.

Commented [SBF3]: Dose standard that accounts for tissue density. Needs discussion.

Commented [SBF4R3]: Took a shot at this. I think the water equivalent dose estimate would be useful to study further as this does contibuet to variability according to subject anatomy. However for our purposes in this profile, we really just need a median reference.

Commented [SBF5R3]: We should also bring up Table 3.6.2 and 3.8.2 with respect to KOD's changes regarding CT dose, which I think was modified on the last call but the google docs is not showing the changes.

Commented [SBF6]: Add this or similar to Open Issues

7. P31 L593

This phantom may lead to some issues with reverse cupping artifacts due to insufficient scattering material.

Response: The phantom is of limited width and ideally would have greater axial extent. However, we have used this phantom extensively for calibrations across active multi-center trials with consistent results. Moreover, we have investigated the impact of scatter on the HU value with and without attenuating material placed on either side of the standard COPD Gene phantom. The typical result in Air inside the phantom is plotted in **Figure A.1** below. Similar behavior is observed for all of the standard density measures. Nominally HU values measured within the central 5-10 mm of the phantom are accurate and not sufficiently impacted by scatter to be of concern for meeting the specifications of the profile. However, future designs of the phantom will take axial extent under consideration and add

Commented [SBF7]: Acquisition, Needs Discussion

Commented [SBF8R7]: Solid water equivalent ovals on either side of the phantom. Total axial extent >= 45cm.

additional water attenuating material of equivalent diameter on either side of the low density foam standards.

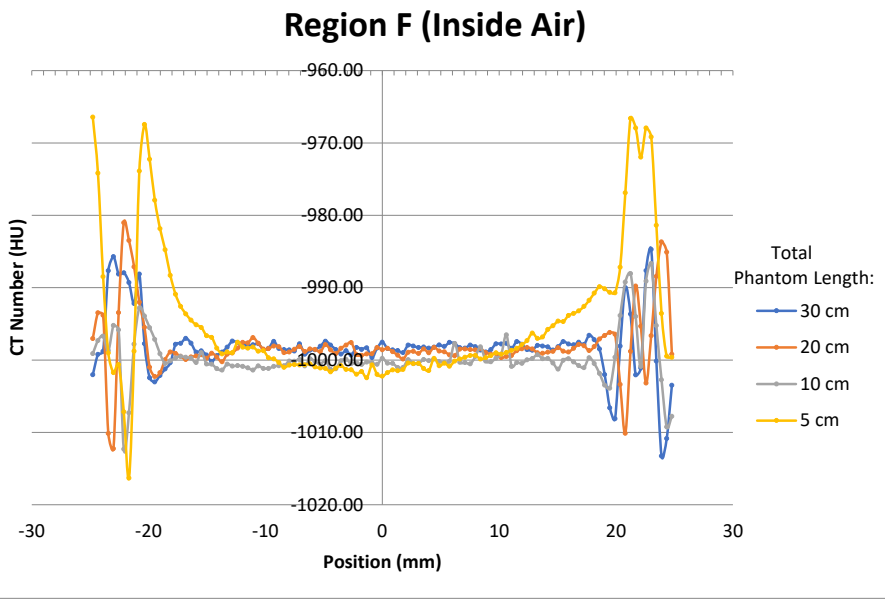

Figure A.1: Axial measures of density for inside air (Region F in Fig. 3) for various axial phantom lengths. CT scan protocol is based on a standard helical protocol with 40 mm Collimation, 0.625 mm Slice Thickness, 200 mA, 120 KVp, Large SFOV, 0.984 Pitch, and 0.5 second rotation time. The gold colored line corresponds to the COPD gene phantom without additional material placed on either side to abut the phantom. While there are non-equlibrium values at the edges, the central 2.0 cm are stable and within the specifications (Nominally -1001.5 HU) required for qualification per Table 3.1.2. Similar behavior is measured for the other density standards in the phantom.

8. P33 L667

The assessment procedures require access to advanced image processing tools that are not available at all sites. Most PACS systems or CT computers don't have a subtract function.

Response: We have chosen to address this comment by specifying, "The diagnostic radiology QMP for a site or vendors may also submit to QIBA proposed

alternative methods with evidence that the results produced by the proposed method are equivalent to the described reference methods."

Image subtraction can be performed using multiple free online software packages such as ImageJ and Fiji (https://imagej.net/Fiji) and the Horos Project (https://horosproject.org) or several free DICOM viewers if the subtraction operation is not available within a site's commercial PACS system. We further recommend that these procedures be performed by the medical physicist on site. The committee recommends that conforming with the profile with respect to independent assessments of signal to noise and spatial resolution are necessary due to the specific demands of quantitative density assessment.

9. P33 L694

Vendors may perform SSP and MTF tests at install as per IEC documents, but likely not for the specific protocol settings and recon kernel for this task. Unclear to me how vendor will confirm that it meets these requirements without additional testing time which is beyond the scope of their normal work and they may charge for.

Response: We have chosen to address this comment by specifying, "The diagnostic radiology QMP for a site or vendors shall confirm that the slice profile, point spread and edge response functions, PSF and ERF respectively, meet the standards specified for scanner qualification (Section 3.1 and Table 3.1.2) and are within adequate range for protocol design (Section 3.4 and Table 3.4.2)."

Again, the committee recommends that conforming with the profile with respect to independent assessments of signal to noise and spatial resolution are necessary due to the specific demands of quantitative density assessment. To some extent achieving this standard may require a culture change within our field.

10. P34 L692

"Shall demonstrate a slice sensitivity profile with FWHM ≤ 1.0 mm as described in Section 4.1.4." However, this document doesn't contain section 4.1.4.

Response: Thank you for identifying this error. The assessment procedure for the slice sensitivity profile is in Section 4.1.3. The reference to this section has been corrected throughout the document.

11.P34 L692

Has anyone studied the variability of FWHM method? The principle of FWHM is straightforward, but its implementation is not. The result can vary significantly if the FWHM curve is not smooth, or the image background contains a graylevel gradient. For example, if the image background contains a graylevel gradient, the baseline of the FWHM curve becomes quite ambiguous. If manufacturers and/or medical physicists implement their own FHWM methods, the likelihood of rather large variability in the measurements is high. Since most physicists are already accustomed to the slice thickness module in ACR phantom or Catphan phantom, the result might be less variable.

Commented [SBF9]: Acquisition needs discussion. Fall back to the ACR or Catphan if necessary.

Commented [SBF10R9]: ACR phantom in the US and Canada(?) Europe (?). Amin and Iowa write a program?

Reword to emphasize the methodology described in 4.1.3. Reference material in COPD phantom, but agree that the ACR and Catphan are preferred. However, these phantoms are not used universally and wished to provide an alternative.

Response:

The FWHM method using the edge response on the phantom does likely require more work. However, its implementation is straight-forward and the committee intends to test this against the ACR and Catphan as a groundwork project. For the time being we have addressed this concern by removing the language regarding the FWHM method in favor of the use of the ACR and Catphan to evaluate in-plane and through-plane spatial resolution.