COPDGene™ Study Quality Assurance Phantom

Philip F. Judy[1] *, Raul San Jose Estepar[1] , Eric Hoffman[2] , David Lynch[3] for the COPDGene™ Investigators, (1) Brigham & Women's Hospital, Boston, MA,(2) University of Iowa, Iowa City, IA, (3) National Jewish Health, Denver, CO

COPDGene
COPD Genetic Epidemiology

http://copdfoundation.com/research/copd_gene_study

Introduction

Image characteristics of a quality assurance phantom designed for the COPDGene™ Study were evaluated. The COPDGene™ Study is a multi-center genome wide association study of chronic obstructive pulmonary disease (COPD). Patients with COPD has a variety of signs and symptoms of the disease. COPD likely has a genetic component. Some obvious evidence that COPD has a genetic component is that most heavy smoker avoid the ravages of COPD.

Quantitative CT evaluation of COPD has proven useful evaluating the severity of the disease.[1,2] COPD related CT phenotypes of interest to the COPDGene™ Study are lung density[3] and bronchial airway dimensions.[4] The COPDGene Phantom has foam material of with a density similar to lung and polycarbonate tubes with dimensions similar to bronchi.

COPDGene Phantom

Figure 1 – Photograph of the COPDGene Phantom

The COPDGene Phantom (Figure 1) consists of a foam inner region (250 mm by 150 mm) to simulate lung surrounded by a soft tissue ring (outer dimensions 350 mm by 250 mm). A 30mm acrylic rod, 30mm air hole, and hole for a water bottle were present in the foam.

Figure 2 – Corneal reconstruction of COPDGene Phantom

Polycarbonate rods to simulate airways with walls were embedded in the foam axially and at 45 degrees (Figure 2).

Tube	Wall Thickness	Luminal Diameter	Orientation
1	0.6	1.5	45 degree
2	0.6	1.5	Axial
3	0.9	3	Axial
4	1.2	3	45 degree
5	1.2	3	Axial
6	1.5	3	Axial

Table 1 – Dimensions of tubes in COPDGene Phantom

COPDGene™ Inspiration Protocol

COPDGene Phantoms were imaged using the CT scanners involved in the Study (Table 2). The inspiration protocol was used: a tube potential of 120 kVp and an effective mAs of 200. Slice thickness ranged from 0.625 mm to 0.9mm. Tube current modulation was off.

The CT number means and standard deviations of the 6 substances were measured using regions-of-interest. The 6 substances were: water, acrylic, air in hole, lung simulating material, soft tissue ring, and air out side phantom(Figure 3).

Scanner Vendor	Scanner Model	Reconstruction Filter	Slice Thickness
General Electric	LightSpeed16	STANDARD	0.625
General Electric	LightSpeed VCT	STANDARD	0.625
Siemens	Sensation 64	B31f	0.75
Siemens	Sensation 16	B31f	0.75
Siemens	Definition - Dual Source	B31f	0.75
Siemens	Definition - AS+	B31f	0.75
Philips	Brilliance 64	B	0.9
Philips	Brilliance 40	B	0.9

Table 2 – CT scanners, kernel, and slice thickness

	CT Number	Standard deviation	Range
Acrylic	119.6	4.1	13.6
Air Inside	-1001.5	3.1	7.8
Air Outside	-1000.3	2.1	6.1
Lung Average	-854.6	2.3	6.6
Ring Average	13.9	5.0	13.5
Water	-0.8	1.7	5.4

Table 3 – Mean CT number averaged over the various scanner designs . Each region-of-interest was averaged over sections that spanned about 30 mm.

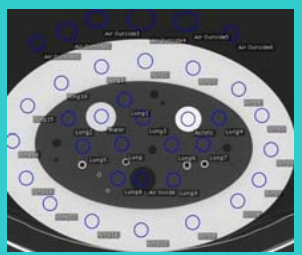

Figure 3 - Phantom regions-of-interest

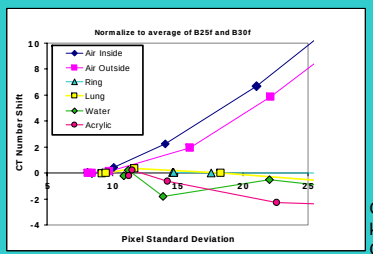

Figure 4 – Variation of CT number as function of kernel (characterized by pixel standard deviation).

Results: Material CT Number Consistency

Standard error of the CT number measurements was less than 1 HU. The CT number of the lung simulating material was -855 HU. A systematic difference between scanners was observed. Note that the largest range of CT numbers was with acrylic, 13.6 HU, more than an order of magnitude greater than the standard error.

Kernel	Stdev	Air Inside
B25f	8.1	-1005.3
B30f	8.5	-1005.4
B40f	10.1	-1004.9
B31f	14.1	-1003.1
B50f	21.0	-998.7
B60f	30.7	-991.0

Table 4 - Reconstruction kernels, air CT number standard deviation and air CT number using the Siemens Definition

Results: Effect of reconstruction kernel

CT Numbers were independent of reconstruction kernel accept when noise causes reconstructed CT numbers to be less than -1024, i.e., lung region. Truncation bias increases the measured CT number and lowers the standard deviation.

Results: Tube size measurements

The wall thickness and the lumen radius of the 6 tubes in the phantom were measured using the FWHM method.[5] These measurements accounted for the tube's orientations and were averaged over sections that spanned about 30 mm. The measurements did not account for the finite resolution.

Tube	Average	Standard deviation	Coefficient of variation		Average	Standard deviation	Coefficient of variation
1	1.459	0.068	4.7%		1.010	0.042	4.1%
2	1.520	0.076	5.0%		0.972	0.049	5.0%
3	1.548	0.083	5.3%		2.609	0.049	1.9%
4	1.671	0.052	3.1%		2.708	0.038	1.4%
5	1.715	0.069	4.0%		2.665	0.042	1.6%
6	1.857	0.065	3.5%		2.758	0.041	1.5%

Discussion

Differences between slice thickness cause systematic differences of emphysema metrics.[6] The slice thickness range was 0.625 mm to 0.9 mm. These systematic differences are caused by variations of noise and sample volume. The systematic variations of phantom CT numbers between scanners are unlikely to be caused by these biases, because the composition within and near the regions-of-interest was constant. These systematic differences are likely caused by differences of the reconstruction procedures dealing with detected secondary x-rays and hardening among vendors.

The CT number of air inside the Phantom is considerable lower (-1001.5) than CT number of air in the trachea of patient CT exams.[7] Figure 5 of data from two of the 64 channel scanner included the Study. The CT number of the trachea is plotted as function of the effective size the patients. The trachea air CT number is substantially greater than air CT number inside the COPDGene Phantom. This suggests that the COPDGene phantom does not capture all the systematic differences of CT evaluations of COPD.

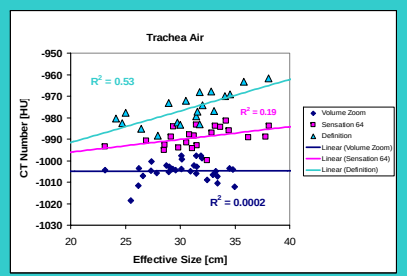

Figure 5 - The CT number of the trachea as function of the effective size the patients. Effective size is geometric mean of AP-PA and Lateral dimensions of the patient in the section

1. N. L. Muller and H. Coxson, "Chronic obstructive pulmonary disease. 4: imaging the lungs in patients with chronic obstructive pulmonary disease," Thorax **57**, 982-985 (2002).
2. J. D. Newell, Jr., "Quantitative computed tomography of lung parenchyma in chronic obstructive pulmonary disease: an overview," Proc Am Thorac Soc 5, 915-918 (2008).
3. A. Madani, V. De Maertelaer, J. Zanen and P. A. Gevenois, "Pulmonary emphysema: radiation dose and section thickness at multidetector CT quantification--comparison with macroscopic and microscopic morphometry," Radiology 243, 250-257 (2007).
4. H. O. Coxson, "Quantitative computed tomography assessment of airway wall dimensions: current status and potential applications for phenotyping chronic obstructive pulmonary disease," Proc Am Thorac Soc 5, 940-945 (2008).
5. O. Weinheimer, T. Achenbach, C. Bletz, C. Duber, H. U. Kauczor and C. P. Heussel, "About objective 3-d analysis of airway geometry in computerized tomography," IEEE Trans Med Imaging 27, 64-74 (2008).
6. G. J. Kemerink, H. H. Kruize, R. J. Lamers and J. M. van Engelshoven, "CT lung densitometry: dependence of CT number histograms on sample volume and consequences for scan protocol comparability," J Comput Assist Tomogr 21, 948-954 (1997).
7. P.F. Judy, R.D. Nawfel, S.G. Silverman, "Systematic scanner variability of patient CT attenuation measurements" in Medical Imaging 2009: Physics of Medical Imaging, edited by Ehsan Samei, Jiang Hsieh, Proceedings of SPIE Vol. 7258 (SPIE, Bellingham, WA 2009) 72582R.

BRIGHAM AND WOMEN'S HOSPITAL

A copy of this poster is available at www.philipfjudy.com from the CT Number accuracy page.