QIBA Quantitative CT: Towards routine quantitative CT in obstructive lung disease

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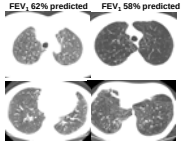
Quantitative CT for COPD Assessment

COPD is Not One Disease

Two Patients, Similar Obstruction

FEV_1 62% predicted FEV_1 58% predicted

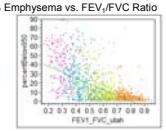


QCT provides sub-phenotypes and facilitates regional analysis

- QCT of emphysema correlates with physiologic evaluation and with histological evidence of emphysema (Basis: CT Density)
- QCT of air trapping correlates with physiologic evidence of airway obstruction (Basis: CT Density)
- QCT of airway wall thickness correlates with histological evidence of small airways disease (Basis: CT Spatial Resolution)

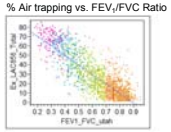
Correlations with Physiology

% Emphysema vs. FEV_1/FVC Ratio



R^2 .46; P < .0001

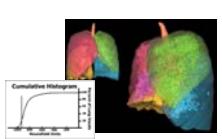
% Air trapping vs. FEV_1/FVC Ratio

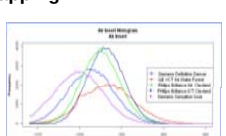


R^2 .72; P< .0001

These graphs show the correlations between the FEV1/FVC ratio and % emphysema (measured as % lung attenuation ≤ -950 HU on inspiratory CT) and % air trapping (measured as % lung attenuation ≤ -856 HU on expiratory CT) in 2273 smokers with and without COPD, enrolled in the COPDGene study. Color coding indicates GOLD stage: Orange= smokers without COPD, yellow= smokers with GOLD Stage I COPD, green= smokers with GOLD Stage II COPD, Blue = smokers with GOLD Stage III COPD, Pink = Smokers with GOLD Stage IV COPD.

CT Attenuation: Biomarkers of Emphysema and Air Trapping





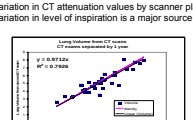
MDCT Scanners:

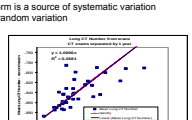
- Almost global availability.
- NIH and industry-based multicenter studies are making use of lung density measures to assess presence, distribution and progression of emphysema, airway wall thickening, and air trapping

However, HU values for air in the trachea and phantoms demonstrate considerable variability between scanner models and manufacturers

Sources of Variation in Measured Lung Attenuation on CT

- Variation in CT attenuation values by scanner platform is a source of systematic variation
- Variation in level of inspiration is a major source of random variation



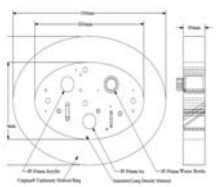


Imaging Phantom for Quantitative CT Studies of Chronic Obstructive Pulmonary Disease

Rationale

In order to standardize quantitative lung CT for the COPDGene Study, a custom designed phantom has been developed to evaluate differences among CT manufacturers and models in lung related image metrics including CT attenuation and spatial (airway) resolution. This phantom is now commercially available (Phantom Labs, Greenwich, NY).

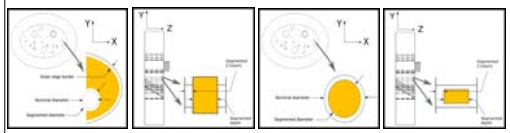
COPDGene Phantom



The COPDGene Phantom (CTP657) consists of an outer water equivalent ring. The center structure consists of a simulated lung parenchyma density (approximately -859HU) which contains a variety of internal holes with and without associated walls of lung-related dimensions. Other structures inside the phantom consist of water (HU 0) and acrylic.

Automated Phantom Analysis Software

Custom made software was developed to automatically segment and analyze the various parts of the phantom



Lung segmentation Lung z-depth Tube segmentation Tube z-depth

COPDGene Protocol

The COPDGene study included 14 different models of scanners. Protocols were made manufacturer and model specific.

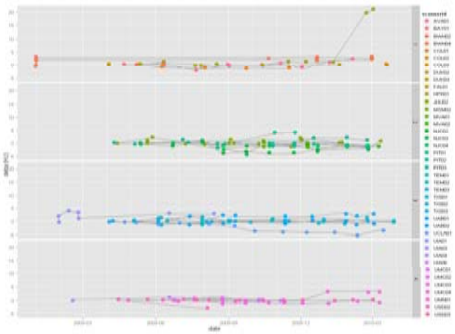
Models of Scanners

Siemens Sensation 16	S16
Siemens Sensation 64	S64
Siemens Biograph 40	SB40
Siemens Definition 64	D64
Siemens Definition AS+	AS+
Siemens Definition Flash	DF
GE Light Speed 16	LS16
GE Light Speed Pro	Pro16
GE Volume CT	VCT64
GE HD 750 CT	HD750
Philips Brilliance	B40
Philips Brilliance	B64

Lung Volumes	INSPIRATION EXPIRATION	INSPIRATION EXPIRATION	INSPIRATION EXPIRATION
Scanner	GE Scanners	Siemens Scanners	Philips Scanners
Scan FOV	Large	NA	NA
RotTime (s)	0.5	0.5	0.5
kV	120	120	120
mA, mAs, eff. mAs	mA: 400/100	Eff. mAs 200/50	mAs 200/50
Pitch	0.984 to 1.375	1 to 1.1	0.923
Dose Modulation	Auto (smart) mA OFF	Care Dose 4D OFF	Dose Right (ACS) OFF
Recon Algorithm 1	Standard	B35,31	B
Recon Algorithm 2	Detail	B45,46	D
Thickness (mm)	0.625	0.625	0.9
Interval (mm)	0.5	0.5	0.5

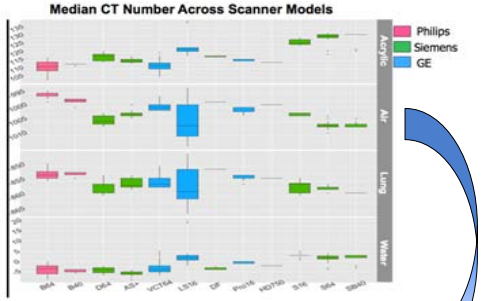
Results

Site Specific Air Density Change (Delta HU from Baseline) Over Time

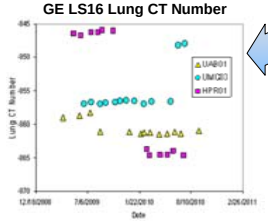


Air measures on a given scanner remained within 3HU of the baseline values except for one site (upper graph) which showed a sudden deviation of 20HU and a second scanner (third graph down) which showed a slow consistent decline to a 5HU deviation from baseline.

Median CT Number Across Scanner Models



GE LS16 Lung CT Number



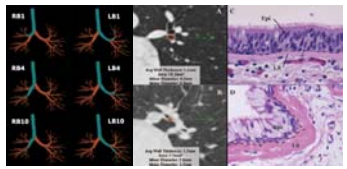
GE LS16 showed the largest deviation in mean CT number, in particular for lung and air. (Right) The variation in lung CT Number is plotted for three study sites using GE (over a three year period)

Quantitative CT for Asthma Assessment

Asthma Biomarkers

Airway Remodeling

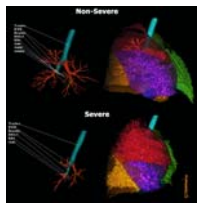
In association with the Severe Asthma Research Project (SARP) it has been shown that CT-based assessment of airway wall thickening correlates with endobronchial biopsy-based assessment of airway remodeling. A set of standardized 6 paths have been established for analysis.



Chest. 2008 Dec;134(6):1183-91

Air Trapping

In association with the Severe Asthma Research Project (SARP) it has been shown that, with a threshold of -850HU on expiratory scans, the lung density mask correlates with pulmonary function tests and distinguishes between severe and non-severe asthma. The COPDGene phantom has been adopted to standardize measurements across study sites.



Chest. 2008 Dec;135(1):48-56

Next steps

- Better understanding of what is considered "normal" on QCT for both inspiratory and expiratory scans.
- Work with manufacturers, using a further modification of the CT phantom, to standardize CT attenuation measurements at lower end of the Hounsfield scale. The phantom measurements will form part of the QIBA profile.
- As part of UPICT, establish imaging protocols for standardized QCT acquisition across manufacturers and scanner models, harmonizing noise, spatial and density resolution.

Evolving Standardization of New Imaging Protocols

Scan Type / Body Size	CTDIvol (mGy)
Inspiration Large (BMI >30)	11.4
Inspiration Medium (BMI 20-30)	7.6
Inspiration Small (BMI < 20)	6.1
Expiration Large (BMI >30)	6.1
Expiration Small / Medium (BMI < 30)	4.2

The table (above left) represents a pre-determined CTDIvol chart which based on small, medium or large subject body size. This may be used as a template to standardize exposure across scanners, as well as minimize the exposure to smaller subjects. Because each manufacturer provides a CTDIvol for a single scan acquisition, CTDIvol can easily be matched across scanners by modifying the milli-amperage of the CT scan.

The figure (above right) demonstrates the proper scan length of a QCT lung scan. Using the proper scan length will minimize the Dose Length Product (DLP), subsequently lowering the effective dose for given subject.