Quantification of Small Airway Dimensions using High Resolution Computed Tomography: A Phantom Study

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INTRODUCTION

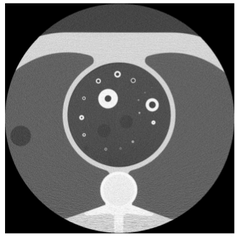
Small airways of inner diameter less than 2 mm are sites of major airflow limitation in patients with chronic obstructive pulmonary disease (COPD) and asthma. Quantitative computed tomography (CT) measurements have shown that wall thickening is associated with airflow limitation at higher generation airways[1].

AIM

To investigate the limitations for accurate assessment of small airway dimensions (inner diameter less than 2 mm) using both super high-resolution (SHR; 160 x 0.25mm detector configuration) and normal-resolution (NR; 80 x 0.5 mm) computed tomography (CT).

METHOD

Phantom Design:
A 10-cm diameter cylindrical polyurethane foam mimicking the lung parenchyma was positioned within an anthropomorphic QRM-Thorax phantom.



- 14 silicone tubing simulating airways : inner diameter (ID), 0.3-3.4 mm; wall thickness (WT), 0.15-1.6 mm.

CT imaging: Aquilion Precision (Canon Medical Systems Corp.) high resolution CT scanner was used to scan the phantom in normal-resolution "NR" mode (0.5 x 0.5 mm physical detector element size) and super high-resolution "SHR" mode (0.25 x 0.25 mm).

- 80, 100 and 120 kV; 10 - 260mA; 0 or 30° gantry tilt angle

Reconstruction:

- Filtered back projection (FBP) and an adaptive iterative dose reduction algorithm (AIDR 3D).
- "SHR-1024": 1024 matrix (0.21 mm × 0.21 mm × 0.25 mm) "SHR-2048": 2048 matrix (0.21 mm × 0.21 mm × 0.25 mm)
- "NR-512": 512 matrix (0.43 mm × 0.43 mm × 0.5 mm)

Airway Dimension Measurement:

- Automated full-width half-maximum (FWHM) method.

RESULTS

Silicone tubing simulating airways

Tube No.	T2001	T2002	T2003	T2004	T2005	T2006	T2007	T2008	T2009	T2010	T2011	T2012	T2013	T2014
ID (mm)	0.3	0.5	0.6	0.8	0.8	1	1.5	1.6	1.6	1.6	2	2.6	3.2	3.4
WT (mm)	0.15	0.2	0.3	0.45	1.58	0.6	0.25	0.4	0.8	1.6	0.6	1.15	1.6	0.6

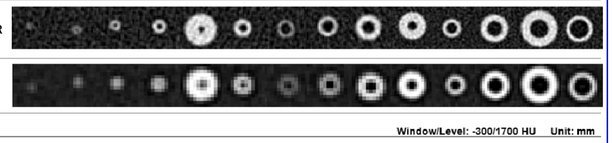


Figure 1. Comparison of 14 tubing using super high-resolution (SHR) and normal-resolution (NR) mode. Images were acquired at 6.2 mGy (260 mA, 120 kV) and reconstructed with filter back projection using the FC30 kernel.

Reliability analysis

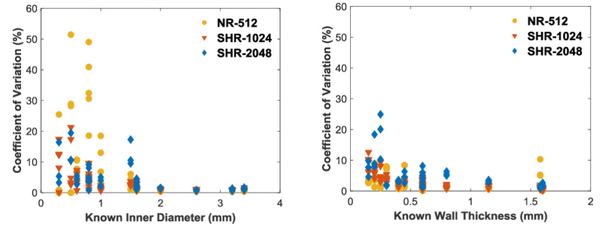


Figure 3. Reliability of tubing dimension measurements using the SHR-2048, SHR-1024 and NR-512 modes. Data shown in graph was acquired at 120 kV, 260 mA using each scan mode. Coefficient of variation (CV) is calculated from independent realizations of each tube dimension by the mean and standard deviation (SD). $CV = SD/mean$.

Linear regression analysis

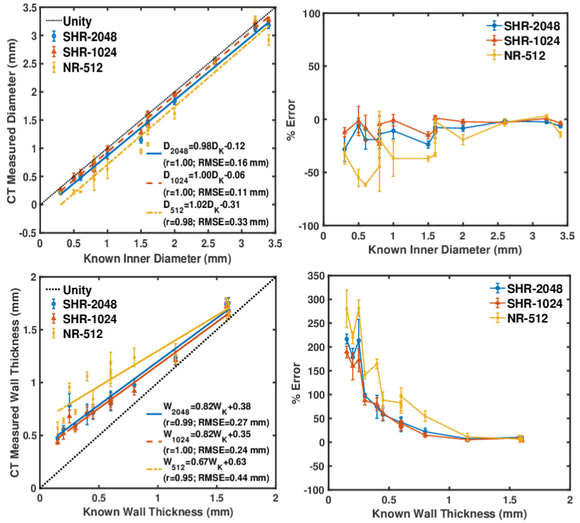


Figure 2. Linear regression analysis and the mean error comparing super high-resolution (SHR-2048, SHR-1024) and normal-resolution (NR-512) scan modes. Top row: inner diameter measurement; bottom row: wall thickness measurement. Data shown in graph was acquired at 120 kV, 260 mA using each scan mode.
RMSE: Root mean square error; $Error\ \% = \frac{CT\_Mesured - Reference}{Reference} \times 100\%$.

Effects of CT parameters: "NR-512" vs "SHR-1024"

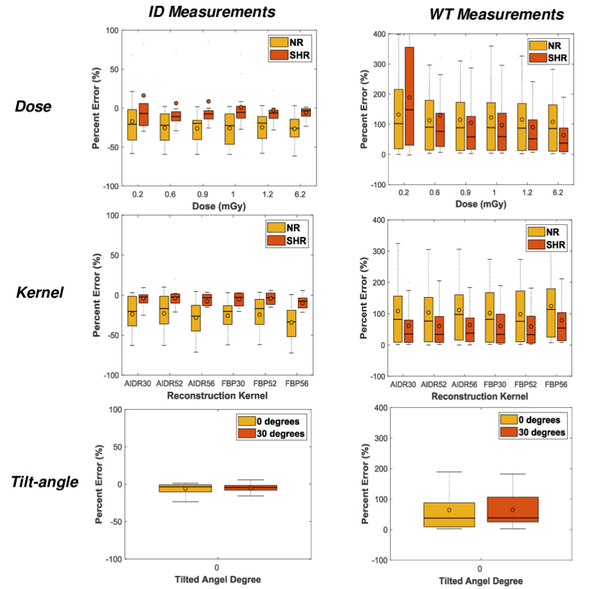
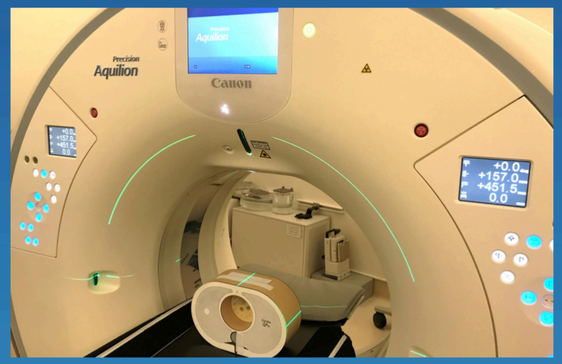


Figure 4. Effects of CT parameters on accuracy of airway dimension measurements, including radiation dosage, reconstruction algorithm and kernel and gantry tilt angle.

CONCLUSIONS

- The inner diameter can be measured within 15% error down to approximately 10th (~1.3mm) and 6th (~2.5mm) generation airways using the SHR and NR modes, respectively.
- High resolution CT can provide more accurate measurement of airway dimensions as compared with normal resolution CT, potentially improving quantitative assessment of pathologies such as COPD and asthma.



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REFERENCES

1. Baron RL, Oliver JH, Dodd GD, Nalesnik M, Holbert BL, Carr B. Hepatocellular carcinoma: Evaluation with biphasic, contrast-enhanced, helical CT. Radiology. 1996;199(2):505-11.

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