The Influence of Reconstruction Algorithm On the Measurement of Airway Dimensions Using Computed Tomography

J.C. Wong, Y. Nakano, N.L. Müller, S.E. Kalloger, K.P. Whittall, H.O. Coxson, P.D. Paré, J.C. Hogg

The University of British Columbia McDonald Research Laboratories / iCAPTURE Centre, St Paul's Hospital, and the Department of Radiology, Vancouver Hospital & Health Sciences Centre , Vancouver, British Columbia, Canada.

Abstract

The assessment of airway dimensions is important in understanding the pathophysiology of various lung diseases. A number of methods have been developed to measure airways on computed tomography, but no study has been done to validate the different CT scanning techniques and reconstruction algorithms. In our study, we constructed an artificial "airway" and "lung" phantom using hollow plastic tubes and foam blocks. The phantom was CT scanned using axial or helical techniques, and the images reconstructed using a very high spatial frequency (GE "lung") algorithm, a high spatial frequency (GE "bone") algorithm, or a low spatial frequency (GE "standard") algorithm. Custom software was then used to analyze the "airways" and measure lumen area (Ai) and "airway" wall area (Aaw). WA% (WA% = 100 x Aaw / (Ai + Aaw)) was also calculated. The cross-sectional area of the lumen and wall of the plastic tubes were measured using an optical micrometer. CT measurements of airway dimensions were virtually identical, comparing axial and helical techniques (p>0.05). Using the plastic tube measurements as a "gold standard", Ai was estimated better with the "lung" or "bone" (4.1 and 7.4 % error) vs. the "standard" (10.4% error) reconstruction algorithm, Aaw better with the "standard" or "bone" (3.8% and 6.2%) vs. "lung" (12.9%) algorithm, and WA% better with the "bone" and "standard" (3.5% and 5.1%) vs. "lung" (7.3%) algorithm. Based on these results, we recommend the high spatial frequency ("bone") algorithm for the CT measurement of airway dimensions.

Background

- The measurement of airway wall dimensions is important for understanding the patho-physiological mechanism underlying lung diseases, such as;
  - asthma
  - chronic obstructive pulmonary disease (COPD)
  - cystic fibrosis
- Computed tomography (CT) may be precise enough to allow quantitative measurements of airway dimensions *in vivo*.
- However, there is no study assessing the effect of the different reconstruction algorithms or the different scanning techniques on the validity of the measurements.

Purpose

- To assess the effect of
  - (1) the different scanning techniques
    - Axial
    - Helical
  - (2) the different types of CT scanners
    - Single-slice
    - Multi-slice
  - (3) the different reconstruction algorithms
    - very high spatial frequency algorithm
    - high spatial frequency algorithm
    - relatively low spatial frequency algorithm

Materials & Methods

Artificial "airway" phantom

- 12 hollow plastic tubes used for axial/helical comparison, 14 tubes for algorithm comparison
- Tubes ranged from 6.35 to 31.75 mm in diameter and were either 1.59 or 3.18 mm thick
- polystyrene foam block was used as the "lung"
- The phantom was placed so that the tubes were perfectly aligned with the z-axis of the CT scanner

CT
Axial/Helical Comparison

- HiSpeed CT/i scanner (GE Medical Systems, Milwaukee, WI)
- 120kV, 200mA and a field of view (FOV) of 20cm
- The scanning technique
  - axial (1 mm thickness)
  - helical (1 mm collimation and pitch of 1.0)

CT
Algorithm Comparison (Helical Scans)

- Lightspeed Ultra Scanner (GE Medical Systems, Milwaukee, WI)
- 120kV, 200mA and a field of view (FOV) of 20cm
- The image reconstruction algorithms
  - very high spatial frequency algorithm (i.e., GE "lung")
  - high spatial frequency algorithm (i.e., GE "bone")
  - relatively low spatial frequency algorithm (i.e., GE "standard")
- The image matrix was 512 × 512

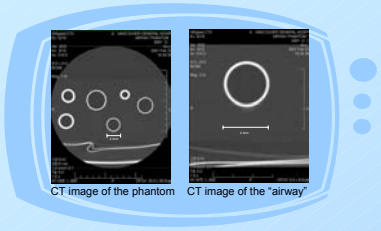
Airway dimensions

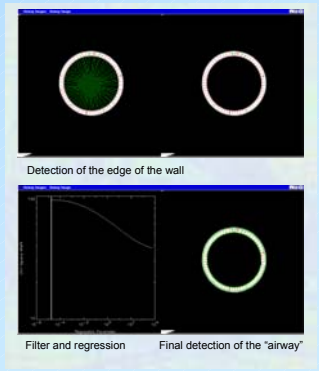
- The area of the lumen (Ai)
- The area of the "airway" wall (Aaw)
- WA% = 100 × Aaw / (Ai + Aaw)

Analysis of airway dimensions using CT

- Development of a custom software
  - Based on a published method

(Am J Respir Crit Care Med 162: 1102-1108; 2000, Proceedings of SPIE 2002;4683:460-469)





"Gold" standard

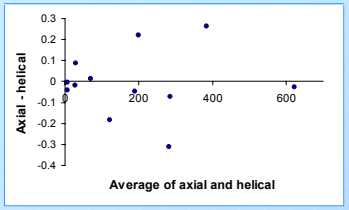
- The diameter of the lumen and the thickness of the wall of the plastic tubes were measured using an optical micrometer
- The cross-sectional areas of the plastic tubes were then calculated

Results

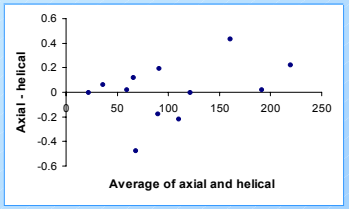
(1) Difference between two scanning techniques

- CT measurements using axial data were not different from those obtained using helical data, if the reconstruction algorithm was the same

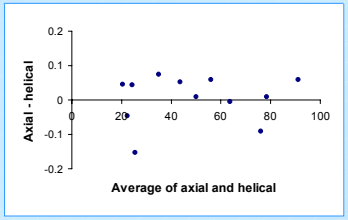
Comparison of Axial vs. Helical
Ai (mm²) for "Bone" reconstruction algorithm



Comparison of Axial vs. Helical
Aaw (mm²) for "Bone" reconstruction algorithm



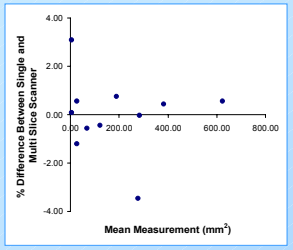
Comparison of Axial vs. Helical
WA% for "Bone" reconstruction algorithm



(2) Difference between single and multi-slice CT scanners

- CT measurements obtained using the single-slice CT scanner were not significantly different from those obtained using the multi-slice CT scanner (r^2>0.99, p>0.05)

Comparison of a Single vs. a Multi-Slice CT Scanner
Ai (mm²) "Bone" Reconstruction

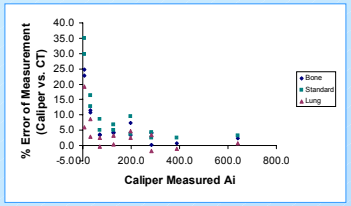


*similar distribution for "lung" reconstruction and Aaw, WA% measurements

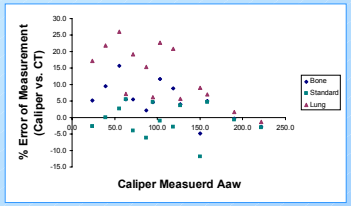
(3) Differences between three reconstruction algorithms

- Ai
  - Ai < 50 mm²
    There is less error in the measurements using "Lung" reconstruction algorithm than "Bone" or "Standard"
  - Ai > 50 mm²
    The error among all three algorithms were almost the same
- Aaw
  - There was less error in the measurements using the "Bone" or "Standard" algorithm
- WA%
  - There was less error in the measurements using the "Bone" algorithm

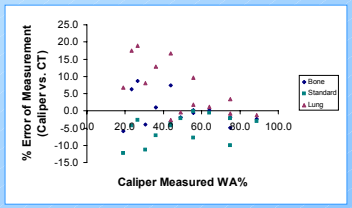
Comparison of Different Reconstruction Algorithms
Ai (mm²)



Comparison of Different Reconstruction Algorithms
Aaw (mm²)



Comparison of Different Reconstruction Algorithms
WA %



Conclusions

- CT measurement of airway dimensions is independent of scanning technique (axial or helical)
- CT measurement of airway dimensions is independent of type of CT scanner used (single-slice or multi-slice)
- A high-spatial frequency algorithm (i.e., GE "Bone") is recommend for the CT measurement of airway dimensions