Wall Thickness Measurement of Respiratory Airway in CT Images: Signal Processing Aspects

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Abstract

Airway wall thickness is an important bio-marker for evaluation of pulmonary diseases such as stenosis, bronchiectasis. Nevertheless, an image-based analysis of the airway tree can provide precise and valuable airway size information, quantitative measurement of airway wall thickness in CT images involves various sources of error and uncertainty. So we have developed an accurate airway wall measurement technique for small airways with three-dimensional (3-D) approach. To illustrate performance of these techniques, we used airway phantom that consisted of 4 acryl tubes with various inner and outer diameters. Results show that evaluation of interpolation and deconvolution methods of airways in 3-D CT images, and significant improvement over the full-width-half-maximum method for measurement of not only location of the luminal and outer edge of the airway wall but airway wall thickness.

I. Introduction

In airway analysis research, tree geometry can be used to help physicians or medical doctors assess pathological conditions, such as stenosis, bronchiectasis. For instance, an unusual reduction in the size of the airway lumen at a particular level in the airway tree may indicate a possible stenosis and an abnormal dilation of the airway represents bronchiectasis. In both cases, the airway wall thickness becomes thickened as compared with normal airways [1]. However, the complexity of morphology and various sizes in bronchial tree make manual analysis difficult and, in addition sometimes noise artifacts, which are occurred in the process of CT image acquisition, reduce the contrast between the wall and lumen, making also airway wall detection difficult. Therefore, in this study, we have developed an accurate airway wall measurement technique for small airways and to validate its accuracy with acryl tube phantoms.

II. Materials and Methods

A set of acryl tube phantom was made to mimic small airways to have three different sizes of wall diameter(4.20, 1.79, 2.98 mm) and wall thickness(1.84, 1.22, 0.67 mm). The phantom was imaged with MDCT using standard reconstruction kernel (Sensation 16, Siemens, Erlangen). The pixel size was 0.488 mm x 0.488 mm x 0.75 mm in x, y, and z direction respectively.

The images were magnified in 5 times using cubic B-spline interpolation, and line profiles were obtained for each tube. To recover faithful line profile from the blurred images, the line profiles were deconvolved with a point spread kernel of the CT which was estimated using the ideal tube profile and image line profile. The inner diameter, outer diameter, and wall thickness of each tube were obtained with FWHM method for the line profiles before and after deconvolution processing.

Ⅲ. Implementation

We used Visual C++ with MFC, ITK (Insight Segmentation and Registration Toolkit) and VTK (Visualization Toolkit) on Win32 environment for developing our 3-D analysis software [2], [3].

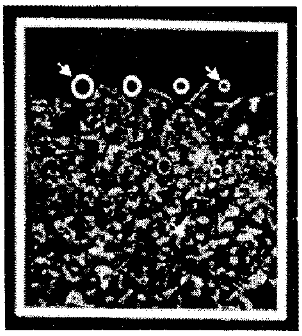

Fig 1. One slice of CT scan of airway phantom used to validate airway geometry measurements.

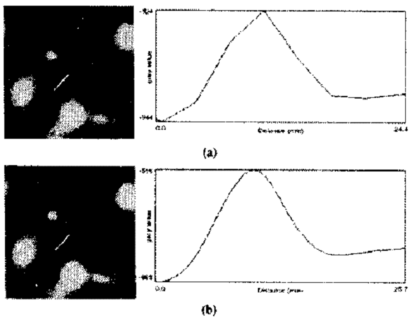

Fig 2. Comparison of reconstructed algorithm using (a) linear interpolation and (b) cubic B-spline interpolation method in 3-D space.

Ⅳ. Conclusion

The FWHM of point spread kernel was 1.33 mm. The wall thickness values were 1.93, 1.48, 1.31 mm before deconvolution, and 1.98, 1.10, 0.70 mm after deconvolution respectively. The magnitude of percent error for each tube reduced from 4.9, 21.3, 95.5% to 7.6, 10.0, 4.5% after deconvolution. The standard deviation of smallest tube was 0.09. By using novel signal processing steps comprising cubic B-spline interpolation, line profile deconvolution, we could measure the wall thickness values within 3% accuracy even on small size tubes with sub millimeter thickness.

This study can be used to evaluate the disease status of COPD, and asthma with MDCT images. For the first time, this study provides a method to measure the thickness of small airways within 5% error (thinner than 1 mm).

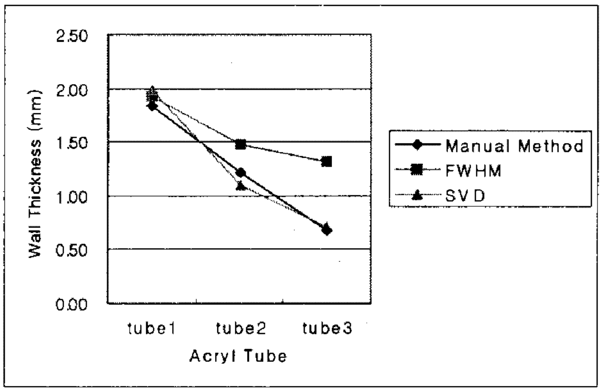

Fig 3. Comparative result of each method on wall thickness measurement

Reference

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