Feasibility of Using Hyperpolarized He-3 Diffusion Weighted Images to Segment the Airway Tree

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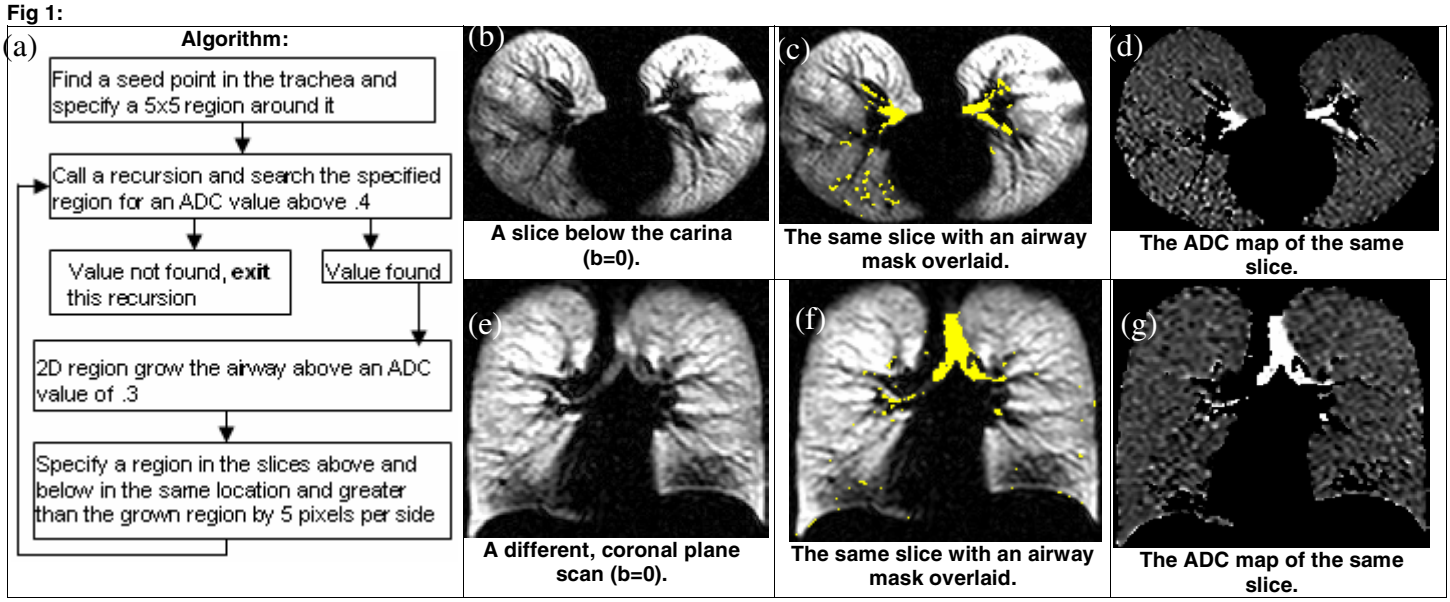
Introduction: Segmentation of the airway tree has been accomplished effectively in CT using region growing techniques (3). While airway segmentation using hyperpolarized (HP) He-3 MRI shows promise due to the high signal provided in the lung airways, adequate contrast between the airways and the lung parenchyma for accurate segmentation remains a challenge (2). The ability to relate airway anatomy to function in the setting of a single MRI exam is desirable for spatially registering structure and function in the evaluation of regional lung diseases such as asthma and COPD. This work explores the feasibility of using the apparent diffusion coefficient (ADC) from HP He-3 diffusion weighted images to segment the airway tree. The rationale is that diffusion within the larger airways is significantly greater than in the restricted airspaces of the lung parenchyma and therefore can be used to separate these structures with high confidence.

Methods: HP He-3 images of the lung airspaces were acquired in human volunteers using a 2D multi-slice SPGR sequence (±15.63 kHz readout bandwidth, 128 × 80 image matrix, 1.5 cm slice thickness, TR/TE of 8.4 msec/4.5 msec and flip angle of ≈ 7°). The images were reconstructed in a series of 13, 256 by 256 pixel slices through the lung. At each slice acquired diffusion and non-diffusion weighted images were acquired (b = 1.6 s/cm^2, $\Delta = \delta = 1.46$ ms). An ADC measurement was obtained for each voxel by applying a two point log-linear fit to the non-weighted image, S_0, and weighted image, S_1, for each subject using: $S_1 = S_0 e^{-bADC}$. It is known that the free ADC of the He-air mixture is between .7 and 1 due to the relatively un-restricted diffusion of the gas in the airways. By combining judicious selection of the ADC threshold with region growing, the airways can be readily segmented from the lung parenchyma and background. This approach was implemented using a recursive guided algorithm (Fig 1a) that mimics three dimensional region growing between the two dimensional slices. This algorithm calls itself on the above and below slices, searches an area, and if it finds a value above an ADC value of .4 it initiates a region growing above and ADC value of .3, the region growing returns a bounding box and then the function calls itself using that box. The ADC thresholds of .4 and .3 were used in order to better detect and fill out the smaller in-plane airways in which the diffusion is somewhat restricted (Fig 1).

Results: Because the diffusion encoding direction is perpendicular to the plane, airways were readily segmented by the proposed algorithm in regions where the diffusion vector was perpendicular to the slice orientation (Fig 1). However, as the airways move oblique to the imaging plane, the algorithm is less successful because there is less diffusion weighting in the airways as they move parallel to the diffusion encoding directions. This can be seen in the ADC maps (Fig 1d, g) where the in-plane airways are practically invisible when compared to the airways in the original image (Fig 1b, e).

Fig 1:



Discussion and Conclusions: The proposed method differs from previous approaches (1, 2) in that it performs region growing segmentation based on the ADC data, and utilizes static breath hold images. This allows an excellent comparison between possible ventilation defects (Fig 1b, e) and the exact location of the airway supplying that region (Fig 1c, f). The segmentation algorithm is completely automated, and works on any axis utilizing ADC data, so it therefore could be readily extended to three dimensions when techniques for fast 3D diffusion tensor imaging, or the trace thereof, becomes available. Specifically, for a 3D diffusion tensor or trace experiment, the diffusion would be less sensitive to the orientation of the slice, in-plane airways would be more readily segmented, and higher ADC thresholds could be used. However, despite the fact that diffusion is encoded only in one dimension, the feasibility of the technique is supported by the fact that it is still capable of detecting some airways that are partially oblique to the slice orientation. Several groups are working on methods to perform diffusion-tensor imaging of the airways in three dimensions (4, 5) and parallel imaging techniques make the prospect for such techniques more promising. Once these imaging techniques are developed, an algorithm such as this can easily and quickly be applied to map out the structure of the airways, which will then lead to a logical correlation between structure and function.

References: 1. Lewis, TA, et al. Magnetic Resonance in Medicine 2005; 53:474-478. 2. Tooker, AC, et al. Radiology 2003; 227:575-579. 3. Tschirren, Juerg, Segmentation, Anatomical Labeling, Branchpoint Matching, and Quantitative Analysis of Human Airway Trees in Volumetric CT Images. 4. Yablonskiy et al., PNAS 2002; 99(5): 3111-3116. 5. Schreiber et al., Respiratory Physiology and Neurobiology 2005; 148:23-42.