A method of regional assessment of lung structure and function using MDCT and Helium-3 MRI

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Introduction

While the pulse sequences and hardware used in hyperpolarized He-3 (HPHe-3) imaging are advancing, the analysis of functional lung images is presently limited to regional qualitative assessment or global quantitative assessment. Quantitative methods have been primarily focused on airway segmentation and measurement [1-4], global or slicewise measures of ADC [5], or oxygen partial pressure [6]. While these measures are of interest, measures corresponding to anatomical structures of physiological interest would be more desirable. Such an approach would allow, for example, identifying the role of abnormal airways at sites of ventilation defects. The lungs, like many organs have natural separations along lobar boundaries that are fed by distinct branch segments of the airway tree. Lobar boundaries are generally difficult to identify on MRI due to poor contrast in proton-weighted images and poor spatial resolution in HPHe-3 images. This work presents a method by which regional information is extracted from a juxtaposition of multi-detector (MD) CT images and MR images by using manual lobar segmentation.

Methods

A GUI was designed and implemented in MATLAB (Mathworks, Natick, MA, USA). Multi-detector CT scans were acquired at 2 lung volumes, TLC and FRC. A total of 5 image data sets can be loaded simultaneously: proton-weighted MRI, HPHe-3 MRI, diffusion weighted HPHe-3 MRI, and MDCT at TLC and FRC. The major steps in the analysis of the data are as follows: 1) Automatic lung segmentation using region growing on the proton-weighted MRI. The resulting segmentation is modifiable on a per slice basis as necessary. 2) Lobe boundaries on the proton image are identified by comparison to CT, and are manually drawn on the proton image itself using a spline smoothed curve. 3) The labeling of lung lobes by manually selecting the regions on the lung mask. 4) Manual segmentation of the ventilation defects on HPHe-3 MRI images using an ROI tool that color codes the defects by lung lobe. The inherent registration of the proton and HPHe-3 MRI data facilitates calculation of defect volume by lung lobe. 5) Finally the lobar percent defected and ADC by lobe are automatically calculated. Once calculated, values are automatically reported, and the images, masks, and results can be saved as a single matlab file for future regional analysis. It should be noted that while the MR images discussed are multi-slice Cartesian acquisitions, any type of acquisition could be loaded, including PET images for example.

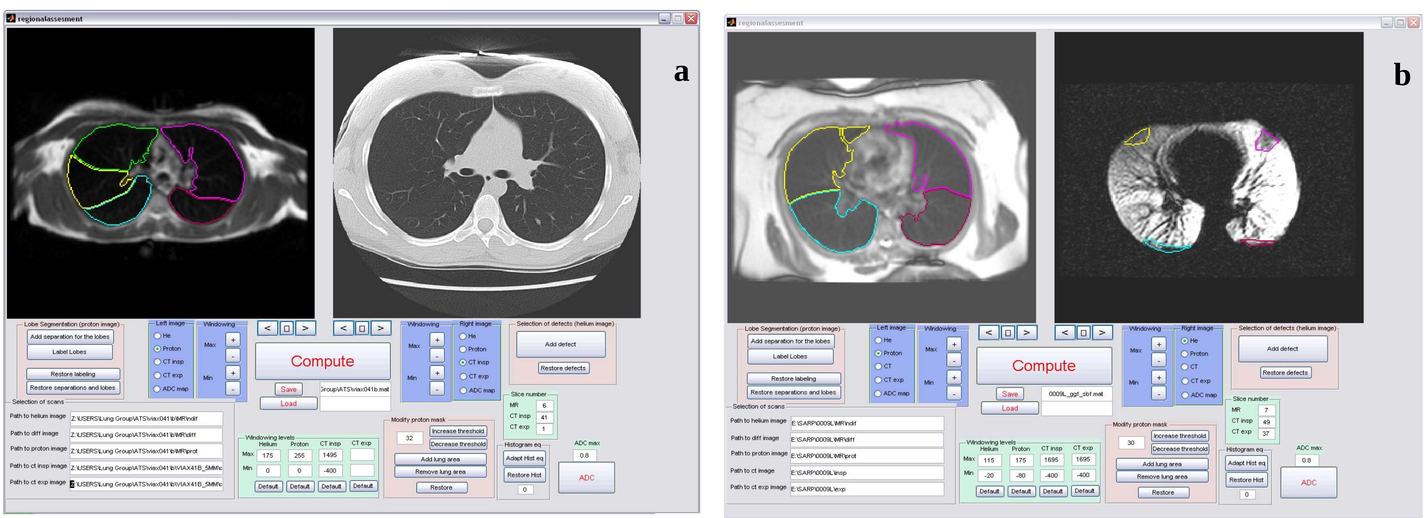

Figure 1: a) An example of the interface, showing a proton MRI scan juxtaposed on the left with the expiratory CT image on the right. b) A different patient with the proton image on the left in registration with the HP He-3 image on the right. In the helium image, it can be seen that the defects are colorized based on the lobe in which they reside.

Results

The volume of MRI ventilation defects found using this method has been shown to correlate inversely with FEV_1%predicted ($r = -0.76$, $p = 0.0002$), and regional correlations between reduced parenchymal density on CT and ventilation defects were found to be associated overall ($p=0.04$), and specifically for the right upper ($p=0.003$), left upper ($p=0.03$) and right middle lobes ($p=0.04$).

Discussion and Conclusion

Quantitative results of defect volume were shown to correlate well with a global measure of lung function, FEV_1%predicted, and with specific locations of reduced parenchymal density in CT assessed regionally by lung lobe. Additionally, quantitative measures such as ADC derived from diffusion-weighted HPHe-3 MRI can be similarly assessed regionally on a lobar level for pre-surgical evaluation of lung reduction surgery, or for dose treatment planning in radiation therapy of lung cancers. Similar parametric maps could be incorporated into this approach including, oxygen partial pressure, T_2^*, flip angle, diffusion tensors or Q-space measures. Incorporation of rigid body and deformable registration methods will allow improved cross-modality comparisons with subsegmental evaluation of airways spatially associated with specific ventilation defects.

References

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