Automated algorithm for calculation of lung defect volume using hyperpolarized He-3 MRI and proton magnetic resonance imaging

G. Gonzalez-Fernandez[1], E. Peterson[2], R. O'Halloran[3], and S. Fain[3]

[1]Electrical Engineering, University of Wisconsin-Madison, Madison, WI, United States, [2]Biomedical Engineering, University of Wisconsin-Madison, Madison, WI, United States, [3]Medical Physics, University of Wisconsin-Madison, Madison, WI, United States

Introduction: Hyperpolarized helium-3 can be used in combination with proton MRI to evaluate lung volume [1]. These images can be acquired without changing patient position and with equivalent inhalation volumes of gas for excellent spatial co-registration. However, current methods [1] do not perform this volume calculation in a fully automatic way, as they require user-supervised selection of regions of interest. Lung defects are regions having below-normal ventilation, which show up as decreased signal in hyperpolarized helium images. This effect is easily confused with large scale variation in coil sensitivity. In this work, we develop a method for automatic detection and estimation of defected areas. With this approach, the percentage of defected lung volume can be automatically determined in patients with obstructive lung disease.

Methods: For each patient two sets of images were acquired. The proton set was a Single Shot FSE with an echo train length of 64, an 8 ms effective TE, 90º flip angle, 31.25 kHz BW, 128x64x15 acquired matrix, and a 3.3x3.3x15 (mm^3) acquired resolution. The helium set was a 2D multi-slice rectilinear GRE, with a TR of 8.4 ms, TE of 3.1 ms, 7º flip angle, 31.25 kHz BW, 128x64x15 acquired matrix, and a 3.3x3.3x15 (mm^3) acquired resolution.

A Matlab program was developed to perform all of the calculations (figure 1). A fixed threshold was empirically chosen by analyzing 200 proton images. After applying this first threshold, an area comprised within the lungs was obtained. The corrected threshold for each slice is calculated by summing the mean signal and 3 times the standard deviation of this set of pixels. After this, adaptive histogram equalization (AHE) was performed in the ventilation set of images. Then, a thresholding technique similar to the one previously described was applied to each image so that defected areas could be found. This type of equalization consists of dividing an image into small regions (kernel size 8x8) and performing histogram equalization for each of the regions. AHE compensated for regional variations in coil sensitivity near the lateral aspect of the lungs. As intended, this method did not significantly alter the intensity of the defected areas due to the size of the kernel used. Blood vessels have a low intensity similar to ventilation defects, however, the location and shape of these two areas are quite different; defects usually have trapezoidal or triangular shapes and are located in the periphery of the lungs, while the blood vessels (which cannot be seen as on ventilation images) have linear shapes and are located mainly in the center of the lungs. A mask in the interior region of the lungs was automatically calculated for each slice of the proton images, taking advantage of these characteristics and was used to remove most of the blood vessels from the defect area map.

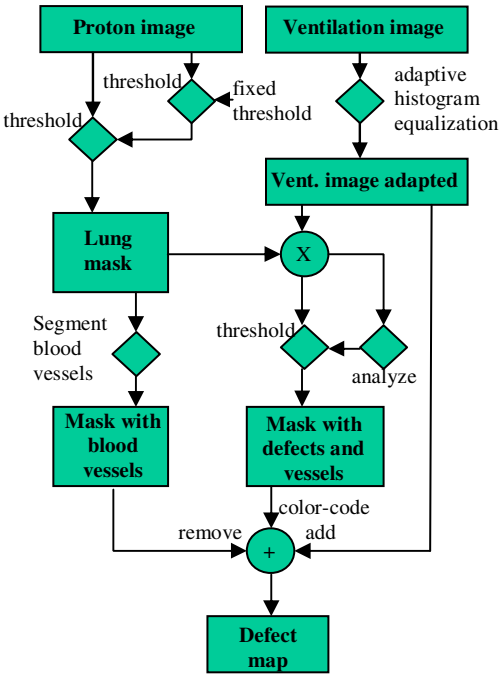

Figure 1: Flowchart of the algorithm for each slice

Results and discussion: The method performs well for patients with a large number of defects and locates and estimates the defect volumes accurately relative to supervised measures (see figure 2). However, in cases with fewer defects, blood vessels near the lung periphery are sometimes included in the defect volume. Future work includes refining the algorithm to correctly define these cases and also address limitations in cases of low SNR that decrease the method's effectiveness. For example, in circumstances of low SNR, the adaptive histogram equalization enhances blood vessels. All of these factors reduce the accuracy of the calculated defected volume. Finally, it should be noted that this method assumes good spatial correspondence between proton and ventilation-weighted images; defect quantification is reduced depending on the extent of mis-registration.

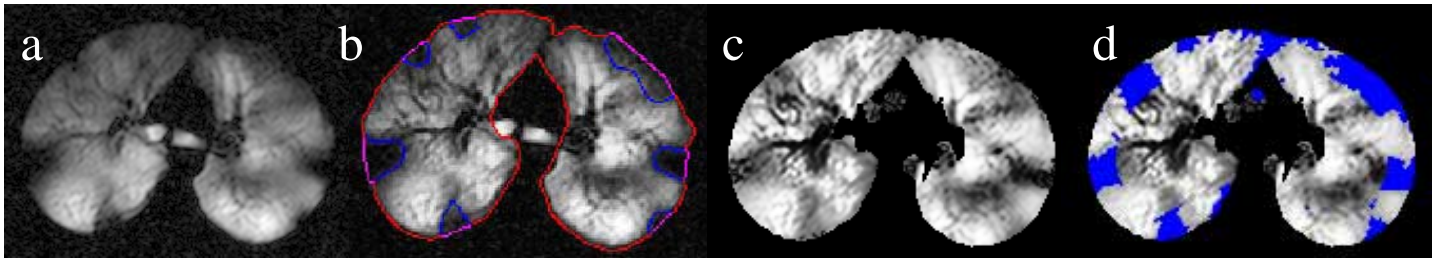

Figure 2: (a) Original image; (b) manually segmented image; (c) image after adaptive histogram equalization; (d) image after automatic detection of defected area (blue).

References

[1] Woodhouse et al. JMRI 21:365-369 (2005)