Semi-Automated Atlas-Based MRI Lung Volumetry

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Introduction: Lung disease accounts for 1 in 6 deaths in the United States with over 35 million Americans of all ages suffering from chronic lung disease (CLD) (1). Pulmonary function spirometry tests (PFT) function as an important measure of lung and airway performance but are limited by an inability to measure individual lung volumes or lung biomechanics directly. Alternatively, as an approach to evaluate individual lung and chest biomechanical properties in relation to regional and diffuse disease, magnetic resonance imaging (MRI) provides several potential techniques to perform direct visualization of the lungs and the subsequent potential for simultaneous multifaceted dynamic lung evaluation. As one cardinal component to a comprehensive MRI examination of the lungs, individual complete lung volumes can be measured by using 3D gradient echo imaging (3D GRE). However, lung segmentation and volumetric assessment is a labor-intensive and time-consuming process limiting the capacity for dynamic imaging analysis.

Purpose: To develop and provide initial validation steps for a lung segmentation toolkit for the purpose of individual lung MRI volumetry as a necessary component of a comprehensive multi-faceted lung MRI exam.

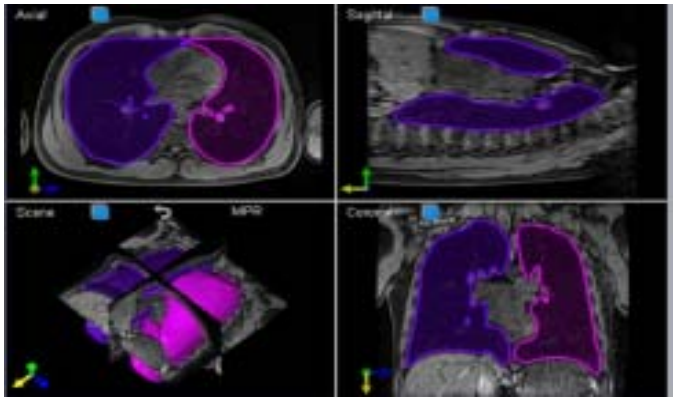
Methods: This study was HIPAA compliant and approved by our internal review board. All subjects provided an informed consent. Six control subjects were recruited from 28-50 years old with no smoking or respiratory disease history. Each subject underwent conventional PFT measurement of total lung vital capacity (VC). MRI was performed using a 1.5T Avanto (SMS, Iselin, NJ). Static volumetric images of the lungs were acquired with 3D GRE (iVIBE) with optimized fat suppression. Static breath hold 3D volumes were obtained with standardized coaching at respiratory cycle extremes (Vmax, Vmin). Utilizing previously developed automated segmentation (2) and atlas-based segmentation methodology which performs point-to-point mapping between a reference image of the chest and the MRI deformed volume (3), the volume extraction algorithm of individual aerated lung parenchyma was applied and collaboratively refined regarding consistent anatomical segmentation. The original baseline atlas was generated from the manual segmentation of two normal volunteers representing a template array of thoracic habitus. From the product of this deformable image registration, normal lung vital capacity (NLC) was measured and compared to the results of the PFT. All post-processing times were recorded.

Results: Table 1 details the correlation between vital capacity measurements using PFT and static MRI at maximum inhalation and exhalation. Imaging outcomes (NLC) underestimated PFT (VC) by an average of 340 mL, exhibiting a persistent bias. The average post-processing time was less than 20 minutes for all subjects. Figure 2 shows a screen-shot example of the software tools used for the MR deformed lung volume post-processing atlas segmentation technique.

Table 1. Correlation of MRI and PFT results

	MRI	Spirometry	Spirometry - MRI
Subject	NLC (L)	VC (L)	Difference
1	4.44	4.46	0.02
2	3.25	3.38	0.14
3	2.83	3.19	0.37
4	3.45	3.92	0.47
5	3.51	4.24	0.73
6	4.50	4.80	0.30
r = 0.77	avg difference = 0.34		standard dev = 0.25

Figure 1: Segmentation software user interface



Discussion: At maximum inhalation and expiration, MRI deformed lung volume extraction measures vital capacity with results near PFT. Unlike PFT, which evaluates the relative total aerated lung volume change from maximum exhalation to inhalation, MRI evaluates absolute individual lung volumes at each respiratory phase with respective morphologic lung assessment. The imaging-based underestimate of VC may be attributable to a difference in subject effort incorporated during spirometry versus the achieved effort during the dynamic MR protocol while in a scanner with accompanying surface coil arrays applied. Alternatively, the MRI underestimate may relate to image post-processing. This discussion point suggests an avenue for future investigation. The atlas segmentation technique facilitates lung image post-processing and allows for rapid evaluation.

Conclusion: Overall, these results demonstrate the potential of further developing our atlas-based automated segmentation toolkit for MRI evaluation of lung volumetry as an essential step towards assessment of individual lung biomechanics.

References:

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