Regional Comparisons of CT Air Trapping and MRI Ventilation Defect Percent in Asthma

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Introduction

Asthma characterized by airway obstruction

Multiple mechanisms of obstruction:
• Mucus plugging
• Smooth muscle bronchospasms
• Inflammatory response
• Airway remodeling
The severe asthma research program’s (SARP) goal is to improve the understanding of severe asthma in order to develop better treatments.
The ventilation defect percentage (VDP) using hyperpolarized He (HP He) MRI has been demonstrated as a measure of ventilation heterogeneity in asthma [Fain].

Similarly, air trapping as measured by the relative lung area below -856HU (RA-856 HU) correlates with asthma severity and worse clinical outcomes [Busacker].
Introduction

MRI and Helium

- Hyperpolarized (HP) $^3$He MRI
  - Enables direct visualization of gas distribution
  - No need for ionizing radiation

Proton MRI

VENTILATION DEFECT

HP $^3$He MRI
Introduction

Air Trapping

- CT expiratory images
  - Threshold of -856 has been shown to correlate well with lung function in asthmatics [Busacker], [Jain].

[Busacker]

![Graph showing percentage of severe asthma, asthma-related hospitalization, and ICU and/or mechanical ventilation with p-values (0.058, 0.005, and 0.004 respectively).]
Rationale

- To compare the regional distribution of ventilation defect to regional air trapping by examining lobar distribution.
Materials and Methods

- **15 patients**
  - (6 males, age 53.5 ± 13.7 years)
- Inspiratory and expiratory CT scans analyzed as part of the Severe Asthma Research Program (SARP) III cohort.
- He MRI and proton MRI
Materials and Methods

Air Trapping Measurement

- Regional Air trapping
  - Functional low density voxels typically assigned to air trapping correspond with lung density values falling below -856 HU on expiratory CT dataset [Busacker].
  - RA -856
Materials and Methods

Measuring Ventilation Defect

The workflow of the adaptive K-means defect quantification: the registered proton image (a) was transformed to obtain a vessel-enhanced proton image (b). The vesselness filter was then applied to estimate the pulmonary vasculature (c). A retrospective...


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Materials and Methods
Lobe Segmentation

- Lobar lung masks were generated from CT using commercial software (VIDA Diagnostics, Coralville, IA).

- The lobe segmentation using VIDA™ was performed on a subset of the CT data [5].
  - Right Upper Lobe (RUL)
  - Right Middle Lobe (RML)
  - Right Lower Lobe (RLL)
  - Left Upper Lobe (LUL)
  - Left Lower Lobe (LLL)
**Materials and Methods**

**Co-registration of MRI He and CT**

- MRI and CT Inspiratory datasets were co-registered using Advanced Normalization Tools (ANTs) ([http://stnava.github.io/ANTs/](http://stnava.github.io/ANTs/)), using a method as described by Thomen et al, Radiology 2015.
Materials and Methods

Regional distribution of VDP

\[ \text{LobarVDP} = \frac{\text{Ventilation Defect Volume (HP MRI)}}{\text{Lobe Volume (Proton MRI)}} \times 100\% \]
Materials and Methods

Regional distribution of Air trapping

- Expiratory CT

- Lung lobes and Airway tree are segmented using commercial software (VIDA Diagnostics, Coralville, IA).

- Regional distribution of air trapping using VIDA
  - Number of voxels within the lung lobe parenchyma with HU less than -856 divided by the total number of voxels in the lung lobe.
Materials and Methods

Statistical Analysis

- Spatial correlation between lobar RA-856HU and lobar VDP was evaluated across 15 subjects (75 total lobes) using Spearman correlation performed in R (https://www.r-project.org).
Results


\[ \text{Spearman Correlation} \]

Lobar measures of RA-856 HU and VDP in a total of 15 subjects (75 lobes) were positively correlated (\( r = 0.63, \ p < 0.0001 \)).
Results

Regional distribution of both VDP and RA-856 is qualitatively similar for the lung lobes with the right middle lobe (RML) being significantly higher compared to all other lobes for RA-856 HU (p<0.012) except the left upper lobe (LUL) for VDP (p<0.03).
Conclusion

- Regional measures of air trapping (RA-856) and Ventilation Defect Percent (VDP) spatially correlate with similar distributions by lung lobe.
- These results suggest that CT Air Trapping may be used as a surrogate metric to measure ventilation heterogeneity in asthma.
- Future research will hopefully elucidate mechanisms of obstruction as they relate to both structure and function.


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