Image Functional Modeling (IFM) using Hyperpolarized Helium MRI

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INTRODUCTION

Anatomically consistent airway tree models were synthesized with Hyperpolarized Helium MRI (HP ^{3}He MRI) imaging data in order to quantify the airway structures responsible for ventilation and mechanical defects in asthmatics. Using an approach called Image Functional Modeling (IFM), we were able to identify the airway constriction patterns necessary to re-create the ventilation defects seen in asthma.

METHODS

In both healthy and asthmatic subjects, we measured lung resistance (R_L) and elastance (E_L) from 0.156 – 8 Hz and acquired static HP ^{3}He images at baseline, post-Methacholine (Mch) induced constriction, and again after a series of deep-inspirations (DIs). Using a conversion factor based on the 1L of inhaled ^{3}He mixture, the percent ventilation of each voxel was identified proportional to the intensity of its pixel. Image processing was then used to convert the intensity HP ^{3}He MRI images to binary image masks (all-or-nothing ventilation). This ventilation information was mapped into a 3D computation lung model (Tgavelekos et al[1]) capable of outputting lung impedance and ventilation distribution based on user-specified constriction. A performance index was used to identify the pattern of constriction that matched best to measured dynamic lung mechanics.

RESULTS/DISCUSSION

Figure 1 shows a single image slice at baseline (left) and following broncho-constriction with Mch (right), where higher intensity pixels indicate ventilated lung regions. At baseline, ventilation appears uniform. Following broncho-constriction, distinct regions of low ventilation are evident and appear heterogeneously throughout the lung slice. Heterogeneous closure of small airways in the model (< 2 mm) was necessary to match ventilation distribution post-Mch. These airway closures (in red) are shown in **Figure 2**. However, matching measured R_L and E_L required additional constriction to the airway tree (those airways proximal to trachea from closures). On average, asthmatics needed a greater standard deviation of constriction both post-Mch and post-DI.

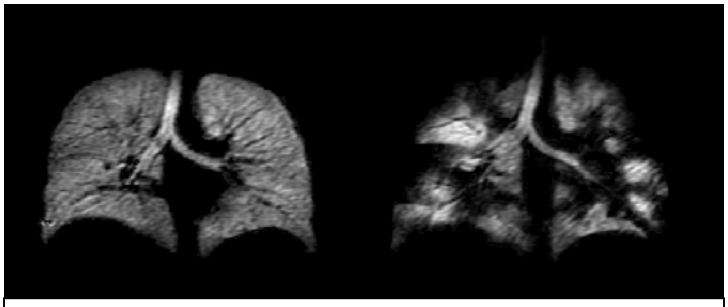

Figure 1 – HP ^{3}He Image slice at baseline (left) and post-Mch (right) in asthmatic lung.

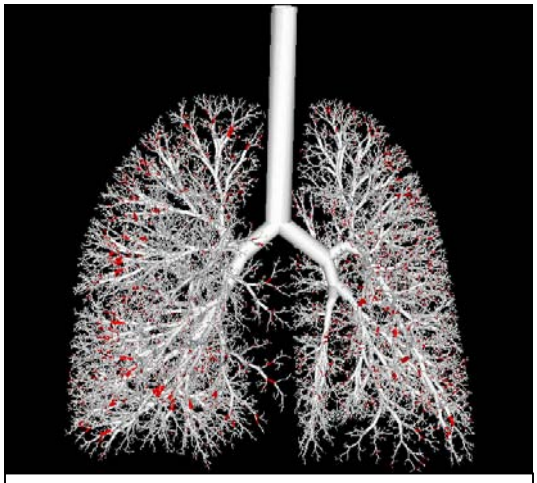

Figure 2 – 3D Airway Tree Model[1]. All airways in red must be closed in order to accurately match image-based ventilation defects for a particular subject.

CONCLUSION:

HP ^{3}He MRI can be synthesized with 3D computational lung models to predict the size and location of airways most responsible for ventilation and mechanical defects in asthmatics, perhaps on a personalized basis.

REFERENCES

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