Airway Behavior Following a Methacholine Challenge Observed Using Hyperpolarized ^{3}He MRI and High Resolution CT

M. S. Albert[1], J. Cook-Granroth[2], J. Gereige[1], J. Mansour[1], K. Lutchen[3], and E. Hoffman[2]

[1]Brigham & Women's Hospital, Boston, MA, United States, [2]University of Iowa, Iowa City, IA, United States, [3]Boston University, Boston, MA, United States

Introduction

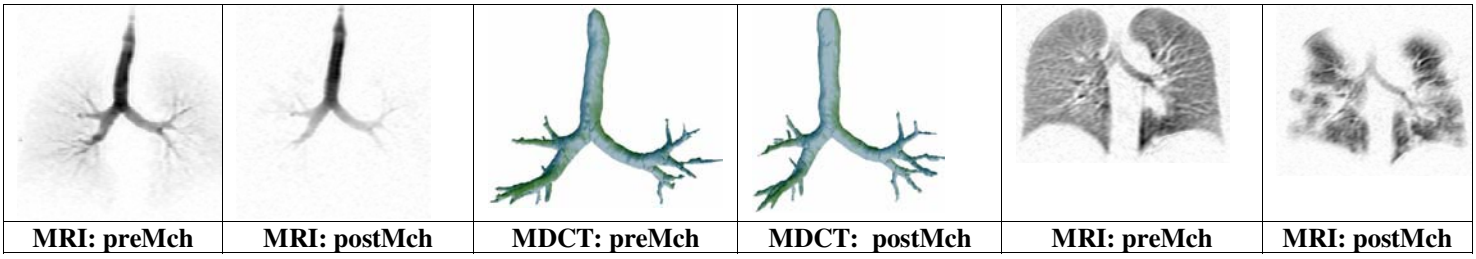
Hyperpolarized ^{3}He MRI (HP ^{3}He MR) is emerging as a method for assessing both regional ventilation and airway anatomy. Simultaneously, multidetector-row computed tomography (MDCT) provides anatomic detail of the whole lung with 0.5mm isotropic resolution during a breath hold of as short as 5 seconds. We have previously used a realistic physical airway phantom, scanned and quantitated via MDCT to validate HP ^{3}He MR-based measures of airway segment cross sectional areas. In this study we have sought to compare HP ^{3}He MR-based images of in vivo human airway tree geometry and regional distribution of ventilation in asthmatics pre and post methacholine versus MDCT measures of the same in vivo human airway tree imaged under the same conditions as during HP ^{3}He MR.

Approach

7 human (5 asthmatic, 2 healthy) volunteers ages 23-60, 3 male and 4 females were studied under approval from our institution's Radiation Safety and Institutional Review Board. In both the MR scanner (GE Signa LX) and the 64 slice MDCT scanner (Siemens, Sensation 64), subjects were studied in the supine body posture. HP ^{3}He MR projection images were acquired from subjects before and after Methacholine challenge. In an effort to focus on the airways, images were acquired dynamically, i.e. while the subjects were inhaling 1 liter of a ^{3}He mixture (33% ^{3}He 66% N_2). Temporal resolution of the MR image acquisition is approximately 400 ms. On a separate day, multidetector-row CT (MDCT) volumetric lung images of the same subject were obtained before and after methacholine challenge. In an effort to match the lung volumes of the day on which the MR images were acquired, the MDCT scans were conducted after the subject inhaled 1 liter of room air from functional residual capacity. Imaging was performed with 100mAs, 120kV, 0.62mm slice spacing. Airways were segmented, automatically labeled, and the middle third of each airway segment was assessed perpendicular to the segment long axis to measure airway segment diameters via the Pulmonary Work Station (VIDA Diagnostics, Coralville, IA). Airway geometry via the MRI scans and CT scans along with down stream ventilation via MRI were then compared.

Results

Significant differences between the MRI and MDCT data were observed. While MDCT demonstrated evidence of airway dilations, it was of particular interest to note that MRI demonstrated the disappearance of some 3rd through 5th generation airways (left two panels) while the corresponding MDCT images (middle two panels) provided quantitative measures suggesting airway segment dilation. The right two figure panels depicts the preMch and postMch ventilation slices from the same subject on a different day, confirming down-stream loss of ventilation.



MRI: preMch	MRI: postMch	MDCT: preMch	MDCT: postMch	MRI: preMch	MRI: postMch

Discussion

These data suggest that small airways constriction are the primary cause for ventilation defects in asthma and that constriction in larger airways often does either not occur at all or there is paradoxical dilation. The dilation may reflect wall distention due to the large downstream constriction that is not explicitly visible. Constriction and increased resistance in the smaller airways coupled with interdependence phenomena, derived from the link between parenchymal tethering may have caused an increase in airway luminal areas that are upstream to more down stream constriction. Since MRI methods only allow for visualization of airways when HP ^{3}He is present, airways could appear to be constricted or truncated up stream due to the failure of HP ^{3}He to travel along that airway path in concentrations detectable by the MR imaging methods used. Since the MDCT and HP ^{3}He MR studies were done on different days, it is un known how day-to-day variability of response might have effected these results. Data-to-date suggest that MDCT and HP ^{3}He MRI provide complimentary information providing needed information to gain insights into the pathophysiology of asthma.

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