MR Grid-Tagging Using Hyperpolarized Helium-3 for Quantitative Assessment of Regional Pulmonary Biomechanics

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Introduction: ^{1}H Magnetic Resonance (MR) grid-tagging has previously been employed for the assessment of myocardial and skeletal muscle mechanics. The application of ^{1}H MR grid-tagging to evaluate pulmonary mechanics has also been reported using an ultra-short TE FLASH sequence [1], but the low proton density in the lungs and high susceptibility effects limit the quality of information obtained with this technique. Hyperpolarized helium-3 (hp He-3) is a gaseous contrast agent that, when inhaled, provides a very high signal from the lung airspaces. A recent study has shown the feasibility of using MR tagging in conjunction with hp He-3 to evaluate lung motion [2]. The purpose of this study was to develop a grid-tagging sequence for hp He-3 and evaluate its ability to quantify human lung biomechanics.

Methods: Six healthy subjects (5 female, 1 male, mean age 46 years) underwent hp He-3 MR imaging on a 1.5 Tesla whole-body MR scanner (Magnetom Sonata, Siemens, Malvern, PA) after inhalation of 150-400cc He-3 polarized to 35-40% (Model 9600, MITI, Durham NC). Grid-tagging was achieved by applying 16 individual sinc-modulated RF pulses with a composite flip angle of 90° prior to the acquisition of the images. Considering the signal decay due to the high diffusivity of He-3 and gas flow during exhalation, a grid with a tag width of 12mm and tag spacing of 12mm was formed to ensure tag visibility on both the inspiration and expiration images. The tagging was followed immediately by a multi-slice FLASH-based acquisition (TR/TE: 4.6/2.2ms; FOV: 300-400mm; matrix: 64×64; flip angle: 5°; slice thickness: 30-200mm) at full inspiration. The subject was then instructed to exhale completely, and the FLASH-based acquisition was repeated following a pause of 2-3 seconds. For each slice, a displacement vector was computed for each grid element; and first and second principal strains (E_1 and E_2) were determined based on the deformed tagging grids that were resolved manually defining the triangular elements with neighbor nodes. Regional ventilation was calculated from matching grid elements on the inspiration and expiration images as the ratio of the difference in grid element volume between inspiration and expiration divided by the grid element volume at inspiration [3].

Results: As shown in Figure 1, the grid tag lines were extremely well defined at inspiration on the hp He-3 MR images and still quite visible, although deformed by the intervening lung movement, at expiration. Lung displacement during exhalation occurred primarily in the cranial caudal direction with the largest displacement in the lung bases adjacent to the diaphragm. The principal strain components, E_1 and E_2, were relatively homogenous throughout the lungs and were predominantly aligned in the vertical and horizontal directions, respectively. Regions close to the heart showed irregular patterns presumably due to the cardiac motion. Quantitative ventilation was generally homogeneous throughout the lungs.

Discussion: These preliminary results demonstrate the feasibility of quantitative assessment of regional pulmonary biomechanics using MR grid-tagging of hp He-3. This technique can quantify regional lung ventilation, and this is the first report demonstrating regional quantification of lung ventilation in humans using hp He-3 MR. With the ability to show local changes in pulmonary biomechanics, this technique could be employed to detect regional pulmonary mechanical dysfunction in a variety of lung diseases that alter pulmonary compliance such as pulmonary fibrosis, emphysema and ARDS.

References: [1] Chen Q et al. MRM. 2001; 45: 24-48. [2] Owers-Bradley JR et al. JMRI 2003; 17: 142-146. [3] West JB Respiratory Physiology 1990.

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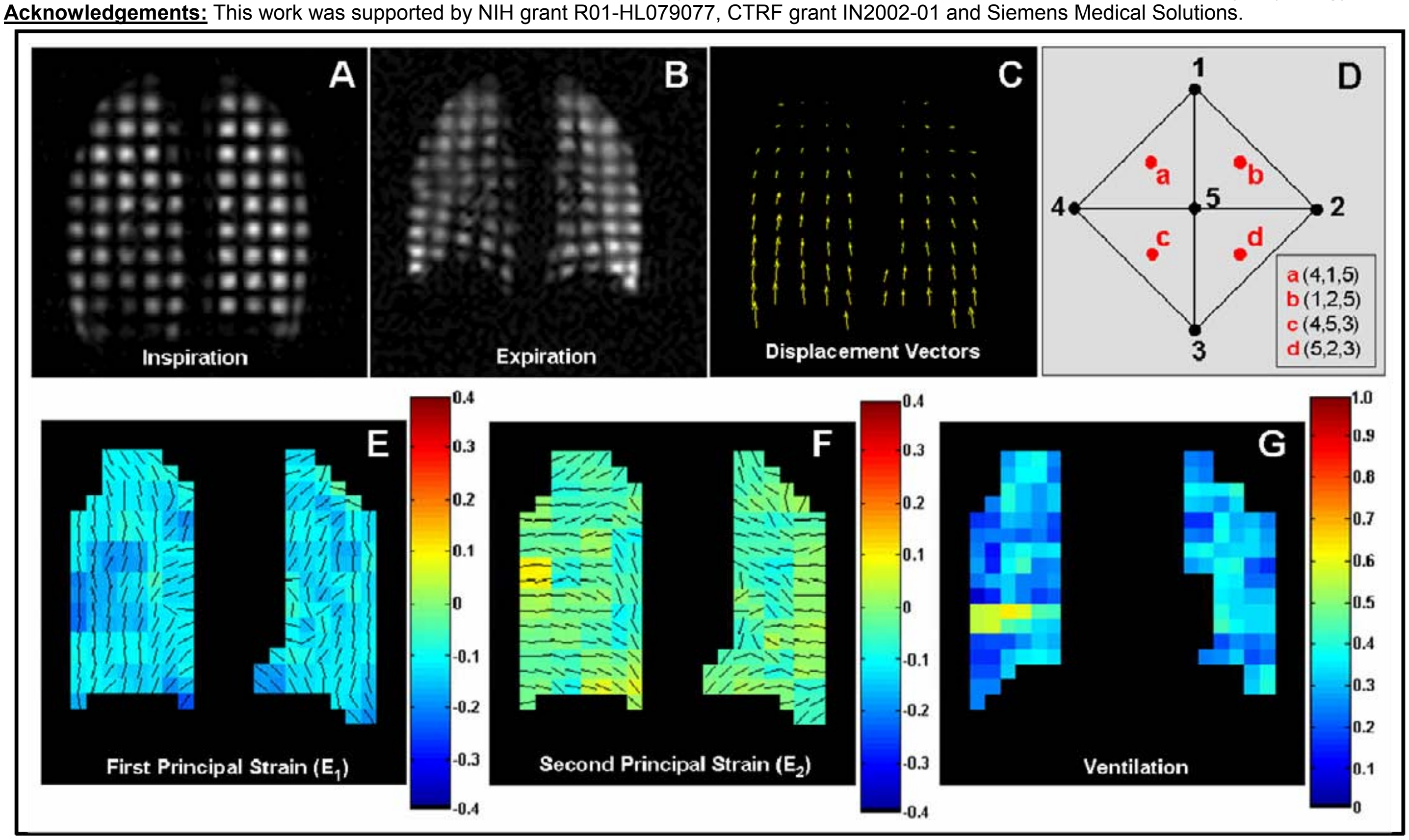

Figure 1. Representative coronal hp He-3 MR images of grid-tagging of human lungs at inspiration (**A**) and expiration (**B**), and the corresponding displacement vector map (**C**), first and second principal strain E1 (**E**) and E2 (**F**) for each triangle element defined as in (**D**), and quantitative ventilation map (**G**).