Combined proton and HP 3He oxygen partial pressure mapping for the evaluation of Acute Respiratory Distress Syndrome

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Introduction: Acute Respiratory Distress Syndrome (ARDS) is characterized by a highly compromised lung function (impaired ventilation and gas exchange) due to inflammation and edema. The purpose of this study was to investigate the potential of combined proton and hyperpolarized (HP) ^{3}He MRI for lung function imaging in a rabbit model of ARDS. Short echo time proton MRI was used to assess the extent of inflammation and edema [1]. The alveolar partial pressure of oxygen (pO_2) and its temporal evolution, i.e. the oxygen depletion time constant during apnea (r), were evaluated using HP ^{3}He MRI [2-4].

Methods: Four animals (specific-pathogen-free white rabbits, mean weight 3 kg) were anesthetized with a ketamine-xylazine mixture. A tracheotomy was performed to control gas administration. ARDS was induced by intravenous injection of 0.1mL oleic acid [5]. Acquisitions were performed on a 1.5T whole-body MR scanner. For pO_2 measurements, 40 ml HP ^{3}He (polarized at 20 %) were insufflated in the rabbit lung. The following imaging protocol was performed at regular intervals during the induction and the development of ARDS.
- 3D FLASH proton imaging (154 mm FOV, ten 6-mm slices, 128^2 image matrix, TR/TE=20/1.17 ms, 30° flip angle, 20 averages).
- for pO2 measurements, 9 spiral projection images (10 interleaved spirals/image, TR/TE=18/2.4 ms, 219 mm FOV, 1.6x1.6 mm^2 pixel size, 128^2 image matrix) with 4-second delay between images were acquired during a 26 s imposed breath hold.
Contrast to Noise Ratio (CNR) in distal regions of the lung was measured in the proton images. Initial oxygen partial pressure p_0 and depletion rate r maps were computed assuming exponential decay of pO_2 during breath-hold.

Results:
The presence and the extent of edema in the lungs were easily visualized on the proton images (Fig. 1). Gradual increase of CNR was observed as a result of edema progression, especially in posterior regions of the lungs, (Fig. 1). Initial oxygen partial pressure and oxygen depletion time constant evolution, averaged over the whole lung, is shown in Fig 2. Both parameters showed a marked tendency to increase with time.

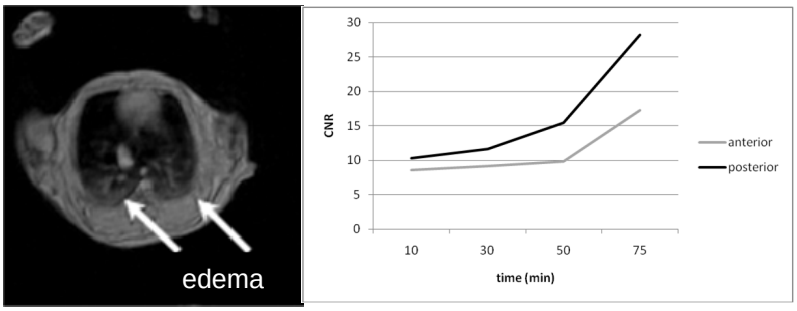

Figure 1: Transverse slice acquired 50 minutes after injection of oleic acid (left) and evolution of CNR in anterior and posterior lung regions (right)

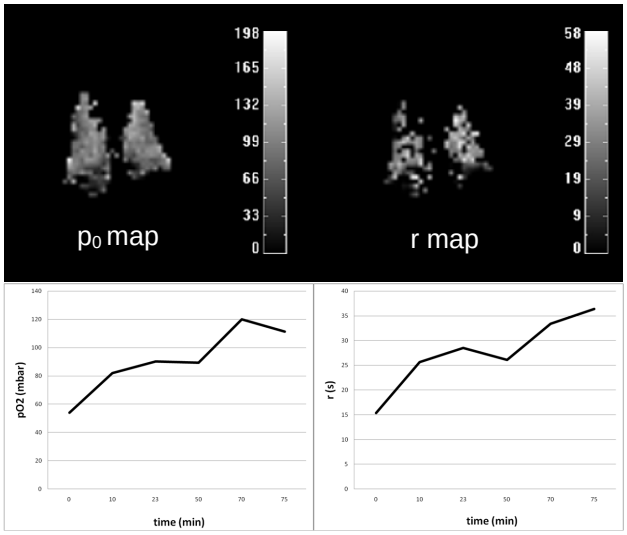

Figure 2: (top) Example p_0 (mbar) and r (s) maps obtained at baseline with the exponential model - (bottom) Evolution of the mean values of p_0 (mbar) and r (s) after injection of oleic acid.

Discussion and conclusion:
Observed changes in p_0 and r values reflect the alteration of ventilation and gas exchange efficiency following onset of ARDS. The p_0 increase can be attributed to hyperventilation (increased breathing rate) following the injection of oleic acid. Furthermore, the increase of r reflects the impairment of oxygen diffusion through the gas-blood barrier. Combined with proton MRI for the visualization of inflammation sites, ^{3}He- based pO_2 measurement will be further used in animal models of ARDS for regional evaluation of disease progression and treatment efficiency.

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