A new acquisition scheme for simultaneous measurement of fractional ventilation, apparent diffusion coefficient and partial pressure of oxygen

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Introduction: In recent years, hyperpolarized helium-3 magnetic resonance imaging (HP ^{3}He MRI) has been used extensively for quantitative assessments of pulmonary structural and functional parameters. Alveolar size airway morphology at the smallest spatial scales can be elucidated using HP ^{3}He MR apparent diffusion coefficient (ADC) imaging. The pulmonary oxygen measurement, which is an example of functional imaging, yields regional alveolar oxygen tension (pO_2) and depletion rate (*ODR*). In our previous work, we proposed a multiple-regression-based single acquisition technique for simultaneously measuring ADC, pO_2 and *ODR*. In this work, we expand this technique and present a new acquisition scheme which additionally includes a characterization of regional air exchange efficiency, termed fractional ventilation (r).

Method: As shown in Fig.1, the new acquisition scheme consists of two parts. The first part is a typical ventilation sequence, in which several breaths of ^{3}He gas are used for fractional ventilation measurement; at the end of the last inhalation of ^{3}He, the breath is held for a single acquisition measurement of ADC and pO_2. The ventilation measurement ends with a high concentration of ^{3}He gas in the lung, which yields a high signal-to-noise ratio for the following images. This benefits the ADC and pO_2 measurement because measurement uncertainty is inversely proportional to signal-to-noise ratio.

Fig.1 diagram of the new acquisition scheme used for simultaneously measuring fractional ventilation, apparent diffusion coefficient and partial pressure of oxygen

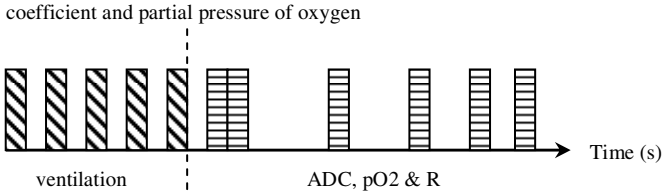
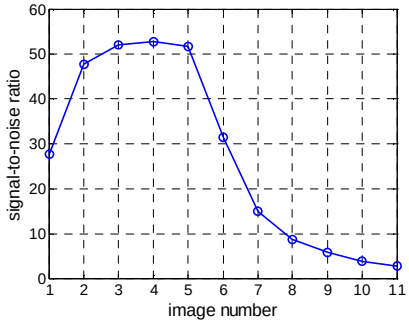
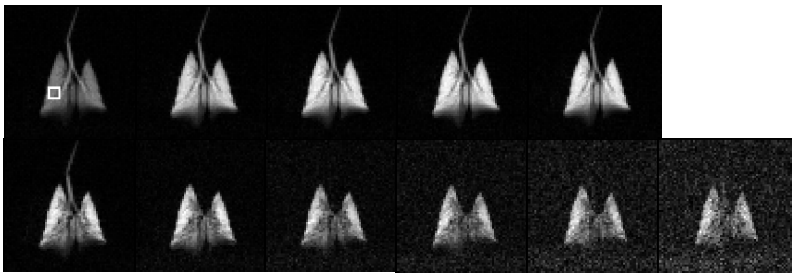


Fig.3 signal evolution of the region-of-interest in Fig.1 (white square box), which represents a typical pattern obtained with the new acquisition.



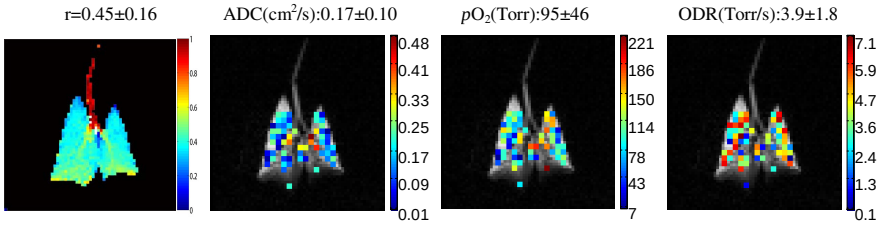
The *in-vivo* animal experiment was conducted under a protocol approved by the Animal Use Committee at the University of Pennsylvania. A New Zealand rabbit was sedated with ketamine and placed supine in a birdcage coil inside a Siemens Sonata 1.5T scanner. The animal was ventilated with a commercial prototype ventilator. In the experiment, a total of 11 images were acquired with the new acquisition scheme. In each breath of the ventilation measurement, a tidal volume of 25ml consisting of 5ml O_2 and 20ml HP ^{3}He gas was administered to the rabbit. A small flip angle gradient echo sequence was used with the following scan parameters: FOV:140mm, three coronal slices; slice thickness:15mm; slice separation:1.5mm; matrix size: 64x64; bandwidth:800Hx/pixel. The first five ventilation images were acquired with TR/TE:4.6ms/2.22ms; the following six images were acquired with TR/TE:10ms/5.81ms due to the insertion of a bipolar gradient in readout direction for diffusion sensitization. The corresponding six gradient factor values (*b* values) are: [0, 1.7305, 1.1506, 0.7056, 0.3305, 0](s/cm^2). The timing used for acquiring the images were [0 2.8100 5.6225 8.4375 11.2575 13.4750 15.3950 23.7150 31.3350 36.9550 40.5750](seconds).

Fig.2 ^{3}He MRI images of a rabbit lung acquired with the new acquisition scheme. The first row shows the fractional ventilation images; the second row shows the ADC&pO2 images.



Result and Discussion: Fig.2 shows the 11 acquired images in the rabbit experiment. It is clear that the signal gradually built up in the ventilation measurement, and then quickly decreased in the ADC& pO_2 measurement. In Fig.3, the signal evolution of a selected region-of-interest demonstrates the exponentially-increase and exponentially-decrease pattern associated with the new acquisition scheme. Fig.4 shows the parametric maps of the four extracted parameters. The fractional ventilation is calculated from the five ventilation images by a non-linear fitting method [1]. The ADC, pO_2 and *ODR* are extracted from the remaining six images by the multiple regression fitting method [2]. It is notable in Fig.1 (second row) that the susceptibility effect dominated the signal in ADC and pO_2 measurement due to the insertion of the bipolar gradient, which suggests a smaller gradient duration should be used in the future study.

Fig.4. Parametric maps of fraction ventilation (r), ADC, pO2 and ODR calculated from the rabbit lung images in Fig.1.



Conclusion: In this work, we present a new acquisition scheme for simultaneous measurement of fractional ventilation, apparent diffusion coefficient partial pressure of oxygen, and oxygen uptake rate.

References: 1.) Emami K *et al.*, A Novel Approach to Measure Regional Lung Ventilation Using Hyperpolarized ^{3}He MRI – Potential in Clinical Studies. ISMRM, 16th Scientific Meeting, 2007. 2.) J. Yu *et al.*, Correlation between the apparent diffusion coefficient and the oxygen depletion rate in COPD disease: a case study. ISMRM, 16th Scientific Meeting, 2007.