Multi-slice PO_2-weighted ^{3}He imaging in a rabbit model of regionally impaired perfusion

G. W. Miller[1], U. Bozlar[1], J. F. Mata[1], C. M. Schamber[1], J. P. Mugler III[1], G. D. Cates[1,2], and K. D. Hagspiel[1]

[1]Department of Radiology, University of Virginia, Charlottesville, Virginia, United States, [2]Department of Physics, University of Virginia, Charlottesville, Virginia, United States

Introduction: Oxygen mapping with hyperpolarized ^{3}He MRI yields quantitatively accurate PO_2 measurements in phantoms when spatially non-selective RF excitations are used [1]. It is generally recognized that to accurately depict steady-state P_AO_2 values in the lung, it is also necessary to ensure that the inhaled gas contains 21% oxygen evenly mixed with the dose of hyperpolarized gas. But just as the goal of conventional ^{1}H MRI is rarely to obtain absolute quantification of T1 or T2, absolute quantification of P_AO_2 may not be necessary to obtain useful information from oxygen maps generated using ^{3}He MRI. By striving simply for PO_2 *weighting*, the sequence programmer is free to use slice-selective excitations to improve SNR and/or spatial resolution, and a much less cumbersome inhalation procedure can be used. The purpose of the present work is to demonstrate the ability of multi-slice oxygen-weighted ^{3}He imaging to depict regional P_AO_2 variations, by applying this technique in an animal model of regionally impaired perfusion.

Methods: Ventilation-perfusion mismatch was created in four anesthetized rabbits using a model of reversible pulmonary embolism. Under fluoroscopic guidance, a balloon angiocatheter was inserted through the right femoral vein and positioned in the left pulmonary artery. Upon inflation, the balloon obstructed perfusion to the lower lobes of the left lung. PO_2-weighted ^{3}He MR images were acquired in each rabbit with the balloon alternately inflated and deflated. Each ^{3}He scan was performed at forced breath hold, immediately following inhalation of 30 ml hyperpolarized ^{3}He, using a 1.5T whole-body scanner (Siemens Sonata) equipped with a homebuilt ^{3}He birdcage RF coil. ^{3}He gas was polarized using a prototype commercial system (Magnetic Imaging Technologies, Inc.)

Two different PO_2-weighted spoiled-gradient-echo pulse sequences were used [1,2]. Both pulse sequences were implemented so as to require acquisition of the fewest possible number of images per scan, and multi-slice capability was implemented by interleaving 2D slice acquisition during the oxygen-sensitization time. Imaging parameters included: TR/TE, 10/3.1 ms; bandwidth, 200 Hz/pixel; matrix, 32×64; pixel size 4×4 mm, oxygen sensitization time, 5s. Slice thickness was 7mm for axial images and 9mm for sagittal images. Pixel-by-pixel P_AO_2 maps were calculated from each set of images using the standard formulas [1,2], but the values served only to provide a quantitative basis for regional contrast and were not interpreted to represent absolute measurements of P_AO_2.

Results: Imaging results were qualitatively similar for all rabbits using both pulse sequences. The fluoroscopic image in Fig.1 shows the position of the inflated balloon (red arrow), and the DSA (digital subtraction angiography) image shows the lack of perfusion to the lower left lung. The coronal-projection oxygen-weighted images show elevated P_AO_2 in the lower left lung with the balloon inflated, in contrast with the small perfused region in the upper right lung (yellow arrows). The axial multi-slice images in Fig.2 also show elevated P_AO_2 elevated in the lower left lung with the balloon inflated (yellow arrows), while the sagittal images show that the boundary of the non-perfused region occurs along a fissure between upper and lower lung lubes (red arrows).

Conclusions: PO_2-weighted ^{3}He imaging is sensitive to regionally obstructed perfusion, and 2D multi-slice application is capable of resolving the location and extent of the affected lung region. The resulting P_AO_2 maps are not absolutely quantitative, but they have good spatial resolution and contrast-to-noise ratio. While ventilation anomalies remain difficult to characterize using oxygen-weighted methods, this study suggests that PO_2-weighted ^{3}He MRI may be useful for identifying perfusion anomalies in the lung. Although the region studied here occupies a large fraction of the rabbit lung, the absolute size of the lesion is relatively small (a few inches), suggesting that respectable spatial resolution is possible in human applications.

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References: [1] Miller GW et al. ESMRMB 22 (2005). [2] Fischer MC et al. MRM 52:766-773 (2004).

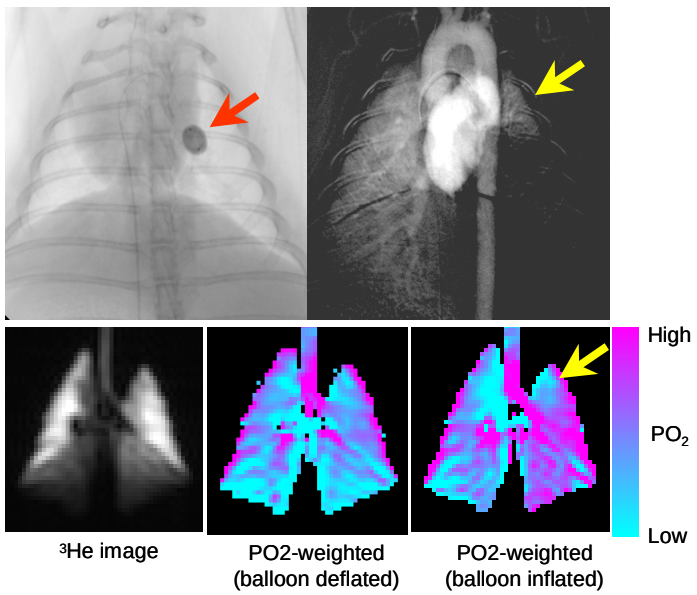

Fig.1: Fluoroscopic and ^{3}He imaging results from rabbit #1.

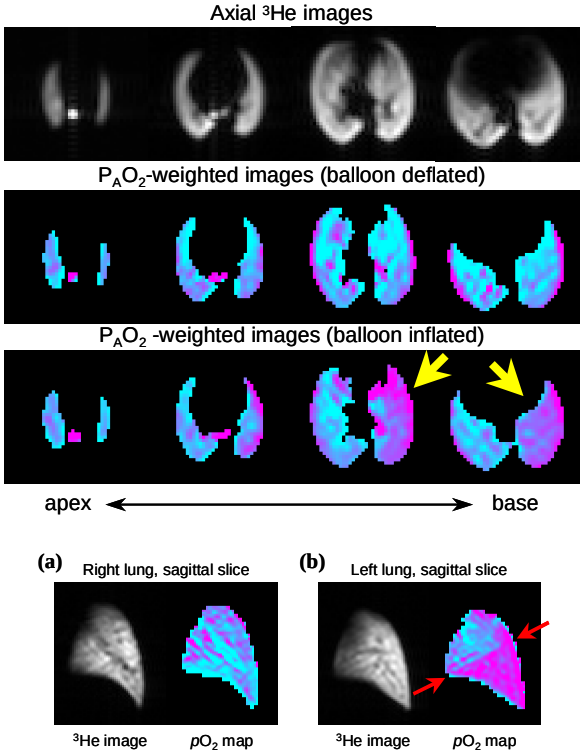

Fig.2: Axial multi-slice ^{3}He imaging results from rabbit #2, and sagittal ^{3}He images from rabbit #3.