Calculation of Regional Partial Pressure of Oxygen and Ventilation / Perfusion Ratio in a Porcine Model of the Normal Lung and the Lung with Perfusion Abnormality

J. Yu1, J. Baumgardner2, M. Ishii1, Z. Z. Spector1, M. Fischer1, J. Han1, M. Itkin1, D. Lipson1, R. R. Rizi1

1Radiology, University of Pennsylvania, Philadelphia, PA, United States; 2Anesthesia, University of Pennsylvania, Philadelphia, PA, United States; 3Otolaryngology, Johns Hopkins University, Baltimore, MD, United States; 4Pulmonology, University of Pennsylvania, Philadelphia, PA, United States

Introduction: A mismatch of the alveolar ventilation/perfusion ratio (V/Q) is the most common cause of hypoxia associated with lung disease. Using hyperpolarized (HP) 3He MRI, we non-invasively and non-radioactively measure regional values of alveolar partial pressure of oxygen (P O2), and from them calculate regional V/Q. The calculations involve a variation on established techniques (1). The method was tested in several normal pigs and in one pig with an artificial pulmonary artery occlusion. Results were obtained in normal regions of each pig lung.

Methods: Yorkshire pigs (25 kg, n=7) were placed in a birdcage coil inside a 1.5 T unit configured to broadband acquisition. HP gas was prepared in a prototype polarizer (Amersham Health, Durham, NC), and administered to the pigs mixed with N2 gas at end expiration. P O2 was measured using Deninger’s double-acquisition imaging technique (2). Blood gas analysis was performed on each pig.

Results: P O2 was successfully measured throughout each normal pig lung based on the 3He MRI images, and values for one normal pig are presented as a frequency distribution (Figure 1A). P O2 frequency distribution for this normal pig displays a single peak centered around 100.00 torr. Measured values show a mean value of 100.49 torr and a standard deviation of 9.80 torr. V/Q values, calculated from regional P O2 values and assumed values for normal mixed venous blood gases in this normal pig, are also presented as a frequency distribution (Figure 1B). V/Q values in the frequency distribution have a mean value of 0.97 and standard deviation of 0.33, and display a single large peak at 0.90.

In the pig with simulated perfusion defect, degradation of 3He signal was observed to be heterogeneous, with rapid degradation of signal concentrated in the lower right lobe of the lung. V/Q values in the region of the simulated perfusion defect were calculated to be slightly higher than in normal regions of the lung. P O2 frequency distribution for this pig displays two peaks, centered at 95.00 torr and 115.00 torr, with smaller peaks at 130 torr and 140 torr (Figure 1C), and with a mean value of 107.66 torr and standard deviation of 19.14 torr (mean value of 100.16 and standard deviation of 12.61 for the normal regions of the abnormal pig lung). V/Q values in the frequency distribution for this pig have a mean value of 1.44 and standard deviation of 1.16 (Figure 1D).

Conclusion: Preliminary results in calculating V/Q from measured P O2 and blood gas concentrations in pig lungs are comparable to trends in V/Q measured in previous studies using such techniques as the Multiple Inert Gas Elimination Technique and nuclear medicine. HP 3He MRI offers a quantitative, non-invasive, and repeatable alternative to these techniques.

Acknowledgment: This study was supported by a grant from NIH grant RO1-HL64741