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

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Introduction: A mismatch of the alveolar ventilation/perfusion ratio (V_A/Q) is the most common cause of hypoxia associated with lung disease. Using hyperpolarized (HP) ^{3}He MRI, we non-invasively and non-radioactively measure regional values of alveolar partial pressure of oxygen (P_AO_2), and from them calculate regional V_A/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 N_2 gas at end expiration. P_AO_2 was measured using Deninger's double-acquisition imaging technique (2). Blood gas analysis was performed on each pig.

Results: P_AO_2 was successfully measured throughout each normal pig lung based on the ^{3}He MRI images, and values for one normal pig are presented as a frequency distribution (Figure 1A). P_AO_2 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_A/Q values, calculated from regional P_AO_2 values and assumed values for normal mixed venous blood gases in this normal pig, are also presented as a frequency distribution (Figure 1B). V_A/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 ^{3}He signal was observed to be heterogeneous, with rapid degradation of signal concentrated in the lower right lobe of the lung. V_A/Q values in the region of the simulated perfusion defect were calculated to be slightly higher than in normal regions of the lung. P_AO_2 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_A/Q values in the frequency distribution for this pig have a mean value of 1.44 and standard deviation of 1.16 (Figure 1D).

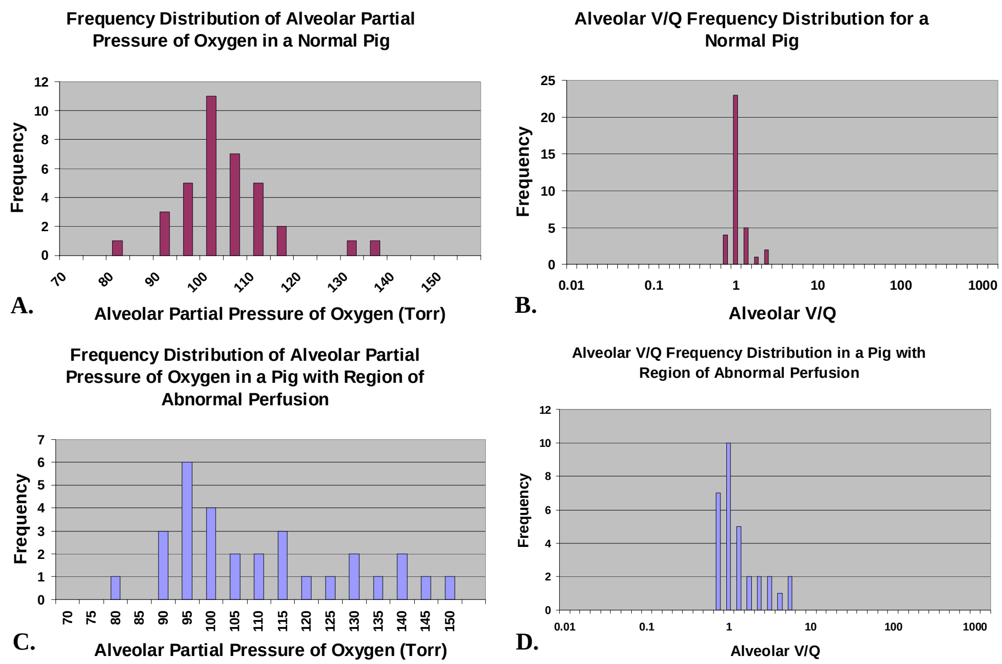

Figure 1. A. Frequency distribution of P_AO_2 in the normal pig lung. Bin size is 5.00 torr. **B.** Frequency distribution of V_A/Q in the normal pig lung. The scale is logarithmic with bin size determined to place eight categories between every integer power of ten (For example, bins are defined by 10^0, $10^{(1/8)}$, $10^{(1/4)}$, $10^{(3/8)}$, $10^{(1/2)}$, $10^{(5/8)}$, $10^{(3/4)}$, $10^{(7/8)}$, and 10^1). **C.** Frequency distribution of P_AO_2 in the pig with an induced perfusion abnormality. Bin size is 5.00 torr. **D.** V_A/Q frequency distribution for the pig with a perfusion abnormality induced with a balloon catheter. The scale is logarithmic with bin size determined to place eight categories between every integer power of ten.

Conclusion: Preliminary results in calculating V_A/Q from measured P_AO_2 and blood gas concentrations in pig lungs are comparable to trends in V_A/Q measured in previous studies using such techniques as the Multiple Inert Gas Elimination Technique and nuclear medicine. HP ^{3}He MRI offers a quantitative, non-invasive, and repeatable alternative to these techniques.

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