Reproducibility of Partial Pressure of Oxygen and Oxygen Depletion Rate in Animal Model

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Introduction: HP MRI measures of regional oxygen tensions provide important insight into a lung's physiologic state during normal and diseased conditions. This stems from a unique correlation between the lung's regional steady state oxygen concentrations and its local ventilation perfusion ratios. A similar relationship exits between the lung's local oxygen depletion rates and its regional alveolar perfusion rates and therefore, makes these measures of great interest to pulmonologists, chest radiologist, and lung physiologist. Despite general interest in these measurements, these techniques are rarely used clinically. A major reason for this is the lack of careful validation and reproducibility studies. We present, to the best of our knowledge, the first HP ^{3}He MRI oxygen and ventilation perfusion ratio reproducibility study. Since cardiopulmonary systems are dynamic, special efforts were made to maintain the test animals under homeostatic conditions during the measurement process. This minimized scatter in the measurement data due to physiologic variability; furthermore, a highly accurate computer controlled MRI compatible ventilator was constructed to ensure that gas delivery was performed in a precise and reproducible fashion.

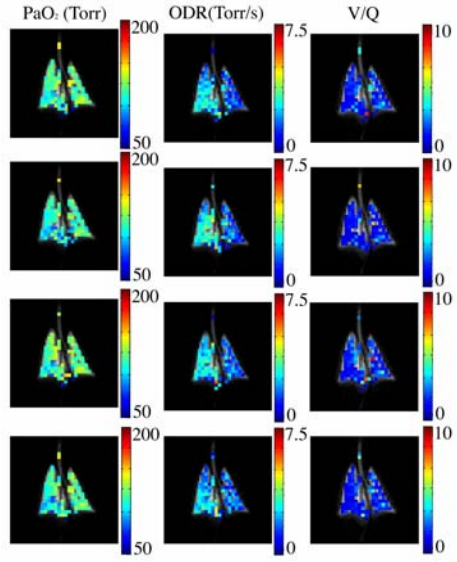

Figure 1. PaO_2, ODR, and V/Q maps as a function of position. Columns from left to right represent PaO_2, ODR, and V/Q. Rows represent sequential measurements. Taken from rabbit number 5. Mean values and SD tabulated in Table 1. Note the how the spatial distributions of the functional parameters are greatly preserved from measurement to measurement.

Method: Six 2.7 to 4 kg New Zealand rabbits were induced, intubated, and maintained using ketamine anesthesia. The rabbits were attached to a computer controlled MRI compatible ventilator and placed in a supine position inside of a solenoidal coil. The tidal volume was fixed at 25 ml. The I to E ratio was set at 1: 4, and the inspired oxygen at 20%. The respiratory rate was set at 50 breaths per minute. The ventilator parameters, except for tidal volumes were then adjusted to maintain the rabbit's end tidal PCO_2 at 40 mm Hg and oxygen saturation greater than 98%. A warming blanket was used to maintain the rabbit's core temperatures within physiologic range. Oxygen experiments were performed using a multislice 2D GE pulse sequence with the following imaging parameters: FOV 140 mm; slice thickness 15 mm; T_R/T_E 7.3 ms/3.6 ms; resolution 64×64; the interscan times were 0, 6.4, 5.7, 3.7, and 1.7 s. During an oxygen measurement, the rabbits were ventilated with a 20%-80% HP ^{3}He-oxygen mixture for one to three breaths. The last HP breath was held while the imaging sequence was run. The polarization of the HP ^{3}He ranged from 30 to 40 percent. Imaging experiments were repeated at roughly two-minute intervals. Cardiopulmonary monitoring was performed to ensure that the rabbits returned to their baseline status prior to performing the next oxygen measurement. Regional oxygen tensions were reconstructed using a multiple regression approach to solve for the oxygen values most likely to cause the changes in MRI signal intensity measured (1). The ventilation perfusion ratios were calculated from the regional oxygen values using the method described by Rizi et.al. (2)

Results and Discussion: Figure 1 depicts reconstructed alveolar partial pressures of oxygen (PaO_2), oxygen depletion rates (ODR), and ventilation perfusion ratios (V/Q) for a sample rabbit experiment. Note how the spatial distribution of the reconstructed parameters remains stable between imaging experiments. In Table 1 we tabulate the mean values and standard deviations for the same experiment depicted in figure 1. These results show that HP MRI measures of oxygen parameters and v/q ratio are highly reproducible.

Conclusion: HP MRI measures of regional alveolar partial pressures of oxygen, oxygen depletion rates, and ventilation perfusion ratios are highly reproducible. These results suggest that HP MRI measures of lung function may lead to a viable clinic modality for following lung diseases that affect regional oxygen tensions, ventilation perfusion ratios, or oxygen depletion rates.

Measurement#	PaO_2 Torr	V/Q	ODR Torr/sec
1	116±16	1.7±1.0	2.1±0.8
2	111±14	1.4±1.0	2.3±1.0
3	118±16	1.8±1.2	2.3±0.9
4	113±16	1.5±0.8	2.1±0.9
5	122±16	2.1±1.4	2.8±1.1
6	117±16	1.7±0.9	1.8±0.9
7	114±15	1.5±0.9	2.1±0.9

Table 1. Table of PaO_2, V/Q , and ODR as a function or measurement number for rabbit number 5. Standard deviations shown as well. Measurement 5 was taken immediately after the HP helium reservoir was changed and may represent an outlying point due to improper mixing of gas during the measurement process.

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References: 1. Yu, et.al., ISMRM 2006. 2. Rizi, et.al., Magn. Reso. Med. 52(1): 65-72 (2004).