Regional Lung V/Q Mapping Using Hyperpolarized 3He MRI and Comparison to Nuclear Medicine: Preliminary Results

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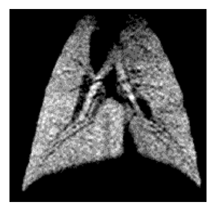
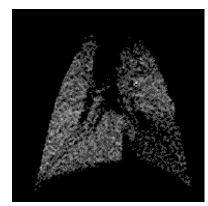
Introduction: Hyperpolarized helium-3 (HP ^{3}He) MRI may be used to obtain regional alveolar O_2 concentrations (P_AO_2) using the technique of Deninger [1]. This regional information may then be used to derive regional V_A/Q ratios by using well-known gas exchange equations [2]. However, while these new HP ^{3}He MRI methods appear promising, they have not been systematically compared to traditional nuclear medicine techniques. Therefore, we compare HP ^{3}He MRI results with those of the traditional nuclear medicine method in normal pigs and in pigs with simulated vascular occlusion using a balloon catheter obstruction of the pulmonary artery.

Methods: This study was conducted in accordance to a protocol approved by the Animal Use Committee Four Yorkshire pigs (20-30 kg) were sedated with intramuscular ketamine (22.0 mg/kg), atropine (0.04 mg/kg), and xylazine (1.0 mg/kg). Following subsequent endotracheal intubation, the animals were maintained under anesthesia using inhaled isoflurane (1.0-2.0%). Hypoxemia and hypercapnia were prevented using volume-controlled ventilation (Drager AV, North American Drager, Inc.). The pigs were ventilated with room air at a tidal volume of 500 cc. Animals were paralyzed with pancuronium (0.2 mg/kg/hr). Intravenous arterial and pulmonary artery catheters were then inserted. Pulse and oxygen saturation were monitored to ensure physiologic stability. To prevent thrombosis, 5000 units of heparin were injected every 30 minutes. In two animals, a balloon catheter was inserted into the right pulmonary artery under fluoroscopic guidance to simulate vascular occlusion. After stabilization, animals were transferred supine to a 1.5 T MRI scanner (GE Signa, Milwaukee, WI) configured for broadband operation for imaging. HP ^{3}He gas was prepared through spin exchange collisions with optically pumped Rb atoms using a commercial prototype noble gas hyperpolarization system (Amersham Health, Princeton, NJ). The ^{3}He gas had an average polarization of 35%. The animals then inhaled 500 cc of a mixture of 80% HP ^{3}He gas (9 mmol/L) and N_2, and 20% O_2. A double tuned (proton, ^{3}He) coil was used for MR image acquisition. For each trial, two sets of ^{3}He images were obtained using a modified gradient imaging pulse sequence with the following imaging parameters: TR = 7.3 ms, TE = 1.9 ms, matrix size = 256 x 128, FOV = 26 x 26 cm, slice thickness = 2 cm, and flip angle = 4 degrees. In each trial, 10 images of a single slice were obtained. The delay between consecutive images in the first series was 1 second. For the second series, the delay was changed to 5 seconds. Upon completion of the MRI scan, the animals were transferred to the nuclear medicine facility. Nuclear medicine images were obtained using a Prism 3000 XP three-head SPECT imaging system (Philips Medical Systems, Andover, MA.) with a low energy general purpose collimator. Animals were ventilated through a Swirler Aerosol Drug Delivery System (AMICI, Inc, Spring City, PA) with 30 mCi ^{99m}Tc-DTPA. The inhalation was discontinued when a count rate of 1000 cps was reached as monitored with a 25 cm long shielded Geiger-Muller tube. For the perfusion images, 5 mCi 99mTc-MAA was injected intravenously, and a posterior planar image was obtained. Images of the lungs were divided into six rectangular regions of interest, which were analyzed using the manufacturer's Odyssey Software package. Nuclear V_A/Q ratios were obtained using the Image Algebra package in the software by taking the normalized number of ventilation counts divided by the normalized number of perfusion counts in each region. For the HP ^{3}He MRI V/Q data, 34 ROIs were obtained and then divided into the same 6 regions as used in the nuclear imaging method. In this manner, the average V/Q ratios were calculated by both methods. Upon the completion of our study, the level of anesthesia was increased and subjects were euthanized with intravenous potassium chloride.





Results and Discussion: In pigs without vascular occlusion, HP ^{3}He imaging revealed homogeneous gas distribution (Left figure). In pigs with simulated vascular occlusion, wedge-shaped defects (Right figure) were observed in the gas distribution corresponding to areas of high V_A/Q. Regions with high V_A/Q would be expected to have higher regional alveolar O_2 concentrations, and, therefore, diminished HP ^{3}He signal. V_A/Q in normal pigs ranged from 0.71 to 1.26 using the HP ^{3}He method, and 0.80 to 1.24 using the nuclear medicine technique. In ROI with vascular occlusion, V_A/Q equaled 3.66 using the HP ^{3}He methods, and was greater than 210 when measured by the nuclear medicine technique.

Conclusion: V_A/Q assessment by HP ^{3}He MRI provides V_A/Q values similar to nuclear medicine techniques. The HP ^{3}He MRI method has the advantages of being noninvasive, non-radioactive, and of higher resolution.

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References:

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