Functional MRI of Obstructive Pulmonary Disease Using a Pig Model

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Purpose
To demonstrate the feasibility of using MRI to assess regional pulmonary ventilation and perfusion using a pig model of airway obstruction.

Introduction
The main function of the lung is gas exchange between the airways and the blood. Therefore, the assessment of regional pulmonary ventilation and perfusion is essential for the diagnosis and evaluation of many lung disorders.

Pulmonary function tests (PFTs) are the current clinical standard for evaluation of airway diseases. Unfortunately, PFTs cannot identify the magnitude and distribution of the diseases on a regional basis. While computed tomography (CT) is considered an accurate method in detecting regional morphologic abnormalities [1-2], it does not provide any functional assessment of lung diseases.

We have recently developed MRI techniques to assess pulmonary function (ventilation and perfusion) on a regional basis. The methods use inhaled molecular oxygen as a T1 contrast agent to assess pulmonary ventilation [3-4] and bolus injection of gadopentetate dimeglumine to assess pulmonary perfusion. Preliminary results have shown great promise of the MRI techniques in assessing regional functional abnormalities, which will be presented below.

Methods
MRI experiments were conducted using a 1.5 Tesla Siemens Vision MRI system. All studies were approved by the hospital Investigational Review Board.

Animal Model: Six Yorkshire pigs were used in a airway obstruction model. The airway obstruction was created by placing a 4-Fr balloon catheter in one of the secondary bronchi of each animal, with the balloon inflated. The animals were intubated and anesthetized (pre-anesthesia with Ketamine 20 mg/kg, xylazine 2 mg/kg and atropine 0.04 mg/kg) throughout the study.

Ventilation MRI: Regional ventilation was assessed by using inhaled molecular oxygen as a T1 contrast agent. Inversion recovery single shot turboSE sequence was used for data acquisition while the animals inhaled room air and O2, alternatively. Centric reordered phase encoding scheme was used to maximize the signal from short T2 species. Imaging parameters were: matrix size = 128 x 256, inter-echo time = 4.2 msec, effective TE = 4.2 msec, section thickness = 8-12 mm, FOV = 40 cm x 40 cm. The delay time TI (600 msec - 1100 msec) between the inversion pulse and the beginning of data acquisition was adjusted to obtain the maximum signal change associated with the inhalation of room air and oxygen. Ventilation scans were created as difference maps from the averaged oxygen-enhanced and room air images.

Perfusion MRI: MR pulmonary perfusion was assessed using a 2D gradient-echo sequence with ultra short TR and TE upon the administration of T1-shortening contrast agents intravenously. Ultra short TE was used to overcome the signal loss due to the short T2* in the lung. Ten ml of gadolinium chelate was administered as an intravenous bolus. The bolus was injected immediately upon the start of the 2D dynamic gradient-echo sequence. A series of 24-36 coronal images were acquired for each of the 5-7 selected slices. Sequence parameters were: TR/TE/FA = 3.0 msec/0.9 msec / 25°, readout bandwidth of 976 Hz/pixel, 8-12 mm section thickness, 128x128 matrix size, FOV = 35 cm x 35 cm.

Results
Figure 1 shows one example of our studies in a Yorkshire pig. In this experiment, the airway supplying the right lower lobe was occluded by placing a 4-Fr balloon catheter in the secondary bronchus, with the balloon inflated (arrow, Figure 1a). As demonstrated in Figure 1b, ventilation deficit distal to the blocked bronchus is readily detected (arrow heads). Matched perfusion deficit due to hypoxic vasoconstriction was also clearly identified using the perfusion MRI technique (arrow heads, Figure 1c).

Figure 2 displays the time course signal changes of MR ventilation and perfusion in the same animal. Notice that little or no ventilation signal change is detected in the region blocked by the obstruction, whereas substantial signal increase is observed in the contralateral normal region (Figure 2a). Decreased perfusion signal is also clearly observed in the abnormal region (Figure 2b).

Conclusion
Our results have shown the feasibility of using MRI to obtain functional information of the lung on a regional basis, which has not been previously possible. The ability of MRI to assess both the magnitude and regional distribution of pulmonary disorders could have significant implication for medical therapy and patient management.

References