Quantitative and Regional Assessment of Emphysema Using Polarized Gas MRI

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Introduction

Emphysema is characterized by the enlargement of airspaces distal to the respiratory bronchioles brought about by the destruction of the walls of the distal airways. Local destruction leads to a derangement in the compliance and airway resistance of emphysematous lungs. As a result regional ventilation is affected. This suggests that regional ventilation may be a useful parameter for diagnosing and following emphysema. In order to determine whether ^{3}He MRI is sensitive enough to measure the ventilation defects characteristically seen in emphysema, we developed a rat emphysema model in which we selectively damage the distal airways using the enzyme elastase. The amount of lung damage can be varied allowing us to study the early and late forms of emphysema. Local fractional ventilation was determined by sequentially increasing the number of hyperpolarized ^{3}He breaths from 1 to 13 prior to imaging the lungs. These series of images provide wash-in data that can be analyzed to obtain the desired local fractional ventilation. Fractional ventilation maps of emphysematous and normal lungs are compared to determine if significant differences exist.

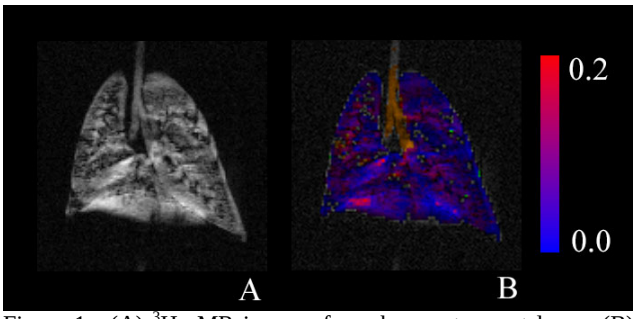

Figure 1: (A) ^{3}He MR image of emphysematous rat lung. (B) Corresponding fractional ventilation color map. Values exceeding the indicated range are depicted in orange.

Method

Experiments were conducted in accordance to an IACAC approved protocol. Emphysema was created in 450 g ± 75 g, Male Sprague-Dawley rats with the application of 20-30U/100g of elastase. Eight weeks were given for the emphysema to develop. The rats were then intubated with a 14 gauge angiocatheter and were maintained on interperitoneal xylazine and ketamine anesthesia. The animals were paralyzed with pancuronium and ventilated using a MRI compatible ventilator (Amersham Health, Durham, NC). Imaging was performed on a small-bore 4.7 T animal magnet (Varian Inc.) using a birdcage coil. The hyperpolarized ^{3}He was generated via the spin-exchange optical pumping method with the use of a commercial polarizer (Amersham Health, Durham, NC). Fractional ventilation was determined using the method introduced by Deninger [1]. The number of Helium breaths ranged from one to thirteen with a tidal volume of 2.5 ml. The helium images were obtained using the following imaging parameters: T_E: 3.3 ms, T_R: 10 ms, FOV: 6 cm, Slice thickness: 4 mm, Flip angle 10°, Matrix size: 128x128. The presence and extent of emphysema was confirmed pathologically. The results obtained were compared to normal rats.

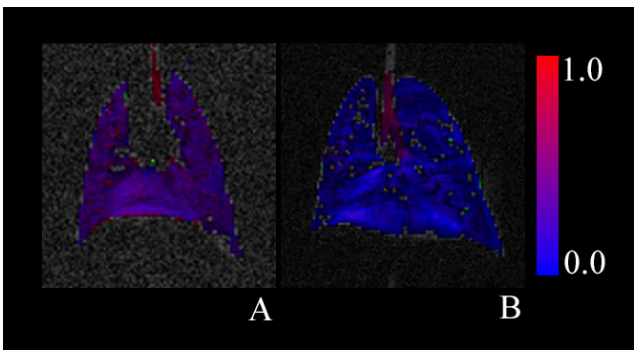

Figure 2: A & B represent fractional ventilation images in a normal and emphysematous lung, respectively. Note how the emphysematous lung is larger and less efficient at ventilation.

Results and Discussion

A sample ^{3}He MR image from an emphysematous rat and its corresponding fraction ventilation map is depicted in Fig. 1. A fractional ventilation map of the same rat is compared with a normal rat in Fig. 2. Note how the distribution of ventilations differs between the normal rat and the emphysematous rat. This difference is depicted more clearly by histograms of the distribution of regional ventilation. These histograms indicate that emphysematous rats are markedly less efficient in ventilating their lungs.

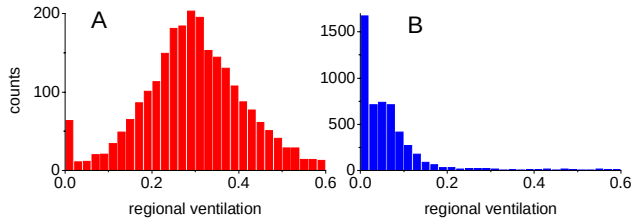

Figure 3: Histograms of the distribution of regional ventilation in a normal (A) and emphysematous (B) rat. Note how the emphysematous rat is far less efficient at ventilating its lungs than a normal rat.

Conclusion

Regional ventilation of normal and emphysematous rats as measured by hyperpolarized ^{3}He MRI show noticeable differences, which suggests that this technique may lead to a new method of detecting and classifying emphysema.

Acknowledgments

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References:

1) Deninger, A.J., *et.al.*, Quantitative measurement of regional lung ventilation using 3He MRI. *Magn Reson Med.* 2002 Aug;48(2):223-32.