Atelectasis: A Useful Evaluation by Hyperpolarized ^{3}Helium Magnetic Resonance Imaging

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Underventilation causes atelectasis, the collapse of lung alveoli. With hyperpolarized ^{3}He MRI (HP-^{3}He MRI), we describe atelectasis in the Yorkshire pig.Under fluoroscopy, 3 intubated pigs underwent Fogarty catheter placement into the right lower lobe. After 45 min of atelectasis, and again after 15 cm H_2O PEEP for 30 min, HP-^{3}He MRI was performed. Additionally, three pigs underwent sodium hydroxide placement into the airway. Nuclear polarization of ^{3}He was accomplished through the spin-exchange collision technique. MRI data were acquired using a rapid three-dimensional gradient-echo pulse sequence.HP-^{3}He MRI uniquely describes atelectasis.

Introduction

Under-ventilation leads to atelectasis: a collapse of lung alveolar units. An estimated 15% of adult human total lung volume is atelectatic[1] and 85-90% of anesthetized adults have atelectasis. Atelectasis may lead to significant hypoxemia[2], lung injury, decreased surfactant[3], pneumonia, and subsequent death. The resolution of atelectasis in intubated patients is one goal of intensive care medicine. Positive end-expiratory pressure (PEEP) changes static hyperinflation, whereas inverse ratio ventilation changes dynamic hyperinflation. We propose to characterize static hyperinflation changes in the porcine atelectatic lung. In this setting, hyperpolarized helium-3 magnetic resonance imaging (HP-^{3}He MRI) offers a unique capability in assessing the diagnosis and treatment of atelectasis.

Materials and Methods

After endotracheal intubation of each Yorkshire pig (n=6), a Fogarty catheter (8/22 Fr; Baxter Laboratories; Irvine, CA) was inserted along the endotracheal tube under fluoroscopic visualization (Figure 1). The pigs were divided into two groups. In the first group, atelectasis was created in each pig using a balloon that was fully inflated for 45 min. HP-^{3}He MR images were taken at baseline, after 45 min of atelectasis (i.e., balloon up), and after PEEP of 15 cmH_2O for 30 min (i.e., balloon down). Nuclear polarization of ^{3}He was accomplished by optical pumping through the spin-exchange collision technique, as previously described [4-5]. MRI data were then acquired as previously described using a rapid three-dimensional gradient-echo pulse sequence[6]. In the second group, atelectasis was created by injection of 3ml of 2-Molar solution of sodium hydroxide. The same imaging protocol as in the first group was followed.

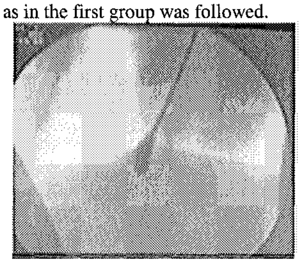

Figure 1: Radiograph demonstrating inflation of a Fogarty balloon occlusion catheter in the right lower lobe bronchus. The balloon was filled with iodinated contrast.

Results

Figure 2 shows HP-^{3}He MRI obtained in the presence of acute airway occlusion, demonstrating a large ventilation defect due to the occlusion balloon. Proton MRI was also performed at this time, confirming the presence of dense right lower lobe atelectasis. Follow-up MRI approximately 30 minutes after balloon deflation demonstrates partial resolution (Figure 3). Figure shows HP-3He images of the lung upon injection of sodium hydroxide.

Discussion

The recruitment of atelectatic lung segments guides ventilator management strategies to improve oxygenation. Typically, one attempts to increase lung volume by increasing either static (e.g., PEEP) or dynamic (e.g., inverse ratio) hyperinflation. HP-^{3}He MR images of Fogarty catheter-induced atelectasis correlate with the anatomic distribution of the right lower lobe. Additionally, static re-expansion of atelectatic alveoli occurs such that distal airways are preferentially inflated before more proximal areas to the obstruction are inflated. These results demonstrate the ability of HP-^{3}He MRI to follow the recruitment of atelectatic alveoli, and further work in recruitment of atelectatic alveoli is warranted.

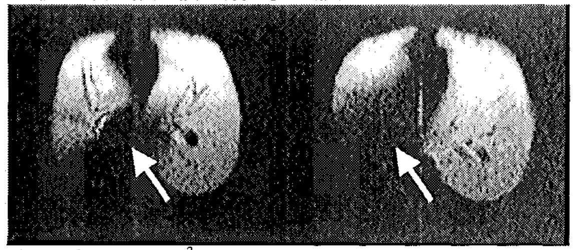

Figure 2: Axial HP-^{3}He images obtained during acute bronchial occlusion in a Yorkshire pig demonstrating a large ventilation defect in the right lower lobe (arrows).

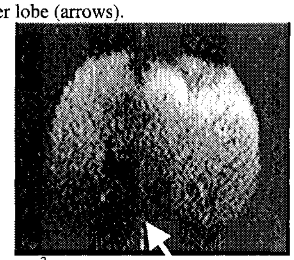

Figure 3: Axial HP-^{3}He images obta.ned approximately 30 minutes after balloon deflation demonstrate partial resolution of atelectasis (arrow).

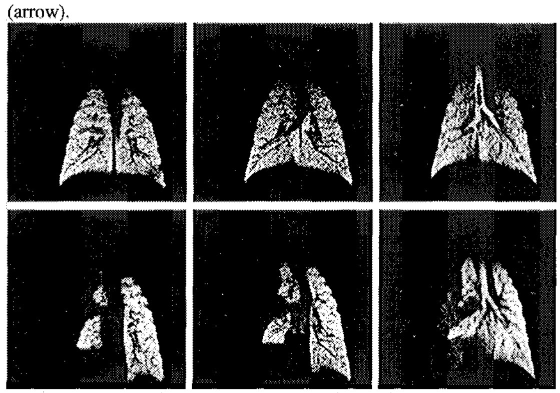

Figure 4: Coronal HP-3He images obtained approximately 10 minutes after injection of sodium hydroxide.

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Acknowledgement

This work was supported by NIH grants RO1-HL64741 and RR02305.