Hyperpolarized 3He MRI of Pulmonary Ventilation in Competitive Breath-hold Divers during Glossopharyngeal Insufflation and Exsufflation

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Introduction

Competitive breath-hold divers are capable of breathing maneuvers that result in extremely large or small lung volumes and transpulmonary presussures. They can inhale well beyond total lung capacity (TLC) by employing glossopharyngeal insufflation (GI, also known as lung packing), to increase stored oxygen in the lungs which helps them to achieve dives exceeding 150 m in depth. During descent, divers employ glossopharyngeal exsufflation (GE, also know as reverse lung packing) to volumes below residual volume (RV), to help equalize pressure in the middle ear. We used hyperpolarized (HP) ^{3}He MRI to study pulmonary ventilation of elite breath-hold divers during performance of these breathing maneuvers at extremely large and small lung volumes.

Methods

Four competitive breath-hold divers (1 female, 3 males), aged 21-32, were studied. The subjects were elite breath-hold divers used to performing GI maneuvers. All subjects were healthy and non-smokers. The HIPAA-compliant research protocol in this study was approved by the local Institutional Review Board. Informed consent was obtained from all recruited subjects. The scans employed a Fast Gradient Echo pulse sequence acquiring coronal multi-slice images with the following parameters: 46 cm FOV, 0.75 PhaseFOV, 128×256 matrix, 13 mm slice thickness, 0 mm gap between slices, 31.25 kHz bandwidth, 14°-18° flip angle, TE/TR 1.228 ms/50-75 ms. All subjects performed hyperpolarized ^{3}He inhalation maneuvers at FRC+1L, and TLC; The divers performed additional maneuvers, inhaling ^{3}He during glossopharyngeal insufflation (GI), to TLC+GI and also from lung volumes approximately 0.5L below residual volume (RV) after GE maneuvers. Static breath-hold imaging was acquired after inhaling a 1 liter mixture of 33% HP ^{3}He- 67% N_2. Dynamic airway imaging was acquired during inspiration of 1 liter of the ^{3}He gas mixture. All subjects were imaged supine.

Results and Discussion

Figure 1. Static breath-hold HP ^{3}He images at FRC (left), TLC (center), and TLC+GI (right) for the same subject.

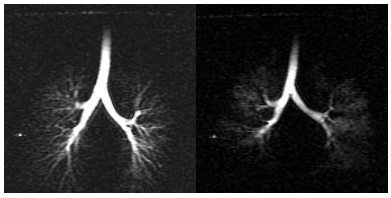

Figure 2. Dynamic airway HP ^{3}He images at FRC (left), and at GE (right) for the same subject.

Figure 1 shows static breath-hold HP 3He images at FRC, TLC and TLC+GI for the same subject. At both FRC and TLC, there is a homogeneous distribution of 3He throughout the periphery of the lung. However, one notices an overall distension of the lungs caused by hyperinflation and a striking appearance of signal hyperintensity of the airways at TLC+GI. The latter is most likely a result of increased transpulmonary pressure caused by GI, which prevents the final inspiration of 3He from leaving the airways and mixing with the rest of lung volume. Figure 2 shows dynamic airway HP 3He images of 1 liter of 3He gas inspired from FRC and after GE. Inspiration from FRC shows airways out to the 6th airway generation. Inspiration after GE, however, shows only 3 generations of airways, which is most likely a result of a highly negative pressure caused by the GE, causing closure of the distal intrapulmonary airways.

Conclusions

After GI, the HP 3He images show hyperintensity of the airways which may be associated with an increase in transpulmonary pressure. Although the GI maneuver increases the amount of gas in the lung, only about one-half of this results in an increase in lung volume, while the rest causes an increase in intrapulmonary gas compression (1). On the other hand, dynamic HP 3He MRI shows a reduction in the amount of visible airway generations after GE, suggesting the closure of some intrapulmonary airways, which corresponds to the decrease of lung volumes and transpulmonary pressures at GE.

References: 1. SH Loring, et al., JAP, 102:841, 2007.