19F Apparent Diffusion Coefficient MRI of Inert Fluorinated Gases in Human Lungs
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Introduction: Hyperpolarized noble gas MRI using 3He or 129Xe has emerged as a powerful technique for detecting microstructural changes in the lungs by measuring the apparent diffusion coefficient (ADC) of inhaled gases. ADC has been previously measured in human lungs using hyperpolarized 3He MRI, which shows a strong correlation with tissue destruction and emphysema (1). More recently, ADC has been measured in patients with chronic obstructive pulmonary disease (COPD) using hyperpolarized 129Xe MRI (2). Although these are very exciting developments, hyperpolarized noble gas MRI is not widely used because it is a complicated and expensive technique that requires specialized hardware. A possible alternative to hyperpolarized noble gases as a probe for measuring ADC is the use of inert fluorinated gases (SF6, C3F8, C2F6) as an inhaled signal source for 19F MRI of the lungs. Density-weighted 19F imaging of inert fluorinated gases was initially reported in rat lungs 14 years ago (3). These gases have the advantages of being nontoxic, abundant, inexpensive, and they do not need to be hyperpolarized prior to their use in lung MRI. ADC measurements using inert fluorinated gas MRI has been previously reported in sealed phantoms (4), in rat lungs (5), and also in excised human lungs (6). Recently, Soher et al. demonstrated the clinical potential of 19F MRI of inert fluorinated gases by performing density-weighted lung imaging in a healthy human subject (7). To our knowledge, 19F ADC measurements have not been previously reported from the lungs of human subjects breathing inert fluorinated gases. In the present study, a 19F 3D ultra-short TE (UTE) ADC pulse sequence was optimized for imaging human lungs with inert fluorinated gases at 3T.

Methods: This study protocol was approved by the local research ethics board and by Health Canada. All subjects provided written and informed consent prior to their participation in this study. Digital pulse oximetry was used to measure oxygen saturation (SpO2) for all subjects during scanning sessions. Imaging was performed using a 3.0 T Philips Achieva scanner with a flexible wrap-around quadrature transmit/receive coil tuned to the 19F resonant frequency (Clinical MR Solutions). The 19F coil was actively proton blocked to allow for 1H imaging while the subject was lying in the 19F coil. 1H images were used as reference scans for planning 3D ADC-weighted 19F images. Immediately prior to imaging, a healthy male subject inhaled a 1 L mixture of 79% C3F8 (perfluoropropane [PFP]) and 21% O2 from a Tedlar bag. During a 33 second breath-hold, two 3D UTE images were acquired: an ADC-weighted image (b-value = 1.33 s/mm2, diffusion time = 1 ms) followed by an image without diffusion weighting. Image acquisition parameters were the following: TR = 34 ms, TE = 2.2 ms, flip angle = 68°, 75% radial sampling density, in-plane FOV = 450 x 450 mm2, matrix = 64 x 64, three slices, thickness = 50 mm and a bandwidth of 140.7 Hz/pixel. Trajectory delays were optimized in order to compensate for eddy currents and gradient delays.

Results and Discussion: Figure 1(a) shows three slices from the 19F 3D UTE image without diffusion weighting. The SNR in the center slice image was approximately 15. Figure 1(b) shows the ADC maps that were calculated from the images shown in Figure 1(a). Figure 2 shows the histograms corresponding to all three ADC maps shown in Figure 1(b). The mean ADC values were 0.034 ± 0.021 cm2/s, 0.023 ± 0.018 cm2/s, and 0.025 ± 0.017 cm2/s for Figures 2 (i), 2 (ii), and 2 (iii), respectively, where the error represents the heterogeneity in each respective ADC map. The ADC values reported in this study are similar to previously published values for the free diffusion of PFP (6). This is to be expected for a diffusion time of 1 ms and the subsequent diffusion length scalar.

Conclusion: This preliminary study effectively demonstrates the excellent potential of 19F 3D UTE for measuring ADC in human lungs using inert fluorinated gases. This technique promises to provide valuable diagnostic information in the diagnosis and treatment of chronic respiratory diseases, such as COPD.

References:

![Figure 1: (a) 19F 3D UTE lung images acquired in a healthy subject, and (b) the corresponding calculated ADC maps.](image1)

![Figure 2: 19F ADC histograms corresponding to the ADC maps shown in Figure 1(b).](image2)