Comparison of Hyperpolarized ^{3}He and ^{129}Xe for Measurement of Absolute Ventilated Lung Volume of Rat Lungs

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Introduction: Magnetic Resonance (MR) imaging using hyperpolarized noble gases (HNG), ^{3}He and ^{129}Xe, provides a non-invasive approach for probing both lung function and structure. In particular, measurement of HNG ventilated lung volumes (e.g. ventilation defects) are useful for characterizing chronic obstructive pulmonary disease (COPD)[1], quantifying xenon diffusing capacity in inflammatory disease [2] and may be useful for assessing lung mechanics (e.g. compliance). It has previously been demonstrated that 3D imaging of ventilated lung volumes in rats using ^{3}He, agrees well with X-ray micro-CT, but without the associated radiation dose, making it useful for longitudinal studies of disease [3]. It would be important to demonstrate similar ventilated volume accuracy and precision using ^{129}Xe, as it is more abundant than ^{3}He and therefore more likely to become a wide-spread clinical tool. The objective of this work was to perform 3-D ^{129}Xe and ^{3}He MR imaging in rats under similar conditions of ventilation and compare measured ventilated volumes obtained with the two different gases.

Methods: Male Sprague Dawley rats (420±20g) were anesthetized, intubated orally, suture-sealed and ventilated using a custom ventilator. Normal ventilation consisted of room air at a rate of 60bpm, tracheal pressure ranging between 12-18cmH_2O and tidal volumes of 8mL/kg. Imaging was performed at 3 T (MR750, GEHC) using an insertable gradient coil having a maximum gradient strength of 50mT/m and two bird-cage RF coils tuned to the appropriate ^{129}Xe and ^{3}He frequencies (35.33MHz and 97.31MHz). Hyperpolarized ^{3}He was polarized to levels in excess of 40% using a turn-key polarizer (Helispin, GEHC). Hyperpolarized ^{129}Xe was polarized to levels of ~10% using a home-built continuous flow xenon polarizer incorporating a cryo-freeze bag collection method. A 3D gradient-recalled echo (3D-FGRE) pulse sequence with variable flip angles (VFA) (3) was used to obtain ^{3}He and ^{129}Xe 3D volumetric images with FOV of 5x5 cm^2, slice thickness of 2mm and matrix size of 64x64x16. Imaging was performed during a four second breath-hold while tracheal pressure (P_{tr}) was matched for both nuclei by suitable adjustment of source gas pressure. Images were thresholded and segmented using seeded region growing (Microview, GEHC) and absolute ventilated volumes |VLV| were calculated using a partial-volume correction algorithm previously described [1].

Results: Figure 1 shows representative ^{3}He and ^{129}Xe volumetric images (surface rendered) from the same rat (pressure = 9.1±0.1cmH_2O). The measured absolute ventilated volumes were 9.74 mL and 9.14 mL for the ^{3}He and ^{129}Xe methods respectively.

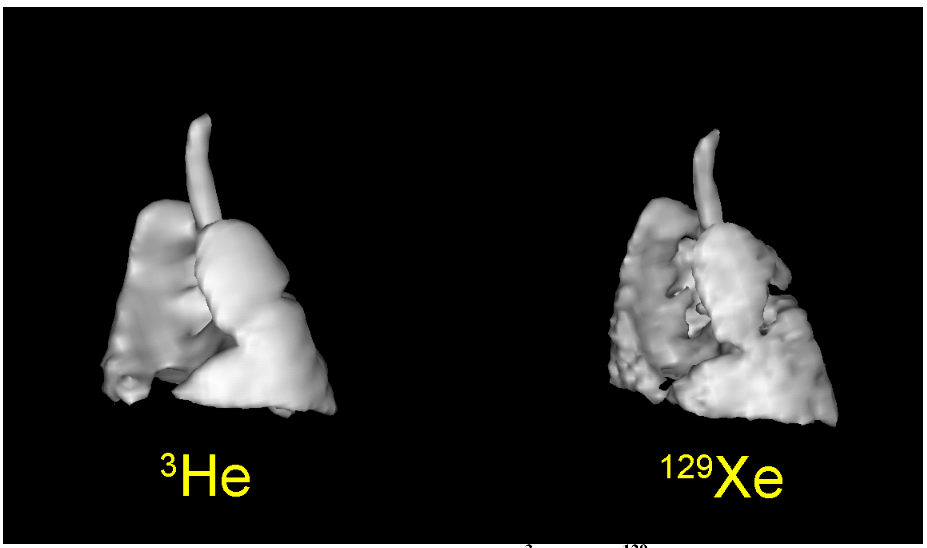

Figure 1: 3D-rendered ventilated volumes in the same rat with ^{3}He and ^{129}Xe respectively under similar breath-hold conditions.

Discussion: The results of this study suggest that the ^{129}Xe MR method can provide accurate and reasonably precise measures of ventilated lung volume as confirmed by a validated ^{3}He MR method. This technique may be important in future as clinical HNG techniques rely more and more on ^{129}Xe due to the unavailability of ^{3}He. However, ^{129}Xe has some important differences. Firstly, ^{129}Xe dissolves into tissue and blood causing the total gas volume to drop as it exchanges with the blood compartment resulting in a pressure drop over time. However, this effect is similar to the effect of oxygen and has previously been demonstrated to contribute negligibly to the measured ventilated volume [1]. Secondly, ^{129}Xe signal-to-noise ratio in this study was less than ^{3}He requiring reduced matrix size and averaging. This may be improved in future by using enriched ^{129}Xe gas mixtures, improved polarizations as well as more efficient pulse sequences. In summary, ^{129}Xe offers a promising alternative to ^{3}He for assessing absolute ventilated lung volumes as well as opening the door to measurement of lung function including exchange with the tissue and blood compartments.

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References: 1. Parraga G. et al. Investigative Radiology Vol 42, Number 6, June (2007). 2. Abdeen N. et al. Magnetic Resonance in Medicine 56:255-264 (2006). 3. Akhavan Sharif M.R. et al. NMR Biomed. (2009); 22: 1-9.