Semi-Automatic Ventilation Defect Analysis Comparing 1-liter and 300-ml 3D Radial and Multi-slice GRE Imaging using Hyperpolarized 129Xe in Non-smoking Older Volunteers

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Target Audience: Hyperpolarized Gas MRI, Clinical MRI Lung Imaging

Purpose: Recently, hyperpolarized (HP) ^{129}Xe MRI has progressed significantly towards clinical use as a probe of pulmonary structure and function[1, 2]. However, while ^{129}Xe MRI scan time is intrinsically short (~15 sec breath-hold), the total exam time, cost, and logistics are limiting factors because it typically requires an hour to produce each liter of ^{129}Xe. Of course, images can be acquired with smaller ^{129}Xe volumes, but this necessitates trading off either image resolution or SNR. This study sought to begin evaluating the effective gain or loss in the quantitative functional information by comparing ^{129}Xe images acquired using both 1-L and 300-ml of ^{129}Xe. We further sought to compare for the two volumes, the relative value of multi-slice GRE imaging and isotropic 3D radial acquisitions. Because previous studies of HP ^{129}Xe MRI reported that ventilation defects increased with age[4], we conducted this imaging comparison in non-smoking subjects over 50 years old. This population exhibited subtle ventilation defects that could be quantified for all images, using both ventilation defect percentage (VDP), as well as linear binning to further stratify the ventilation patterns into four-intensity clusters[5].

Methods: Six non-smoking subjects (3 males, 3 females, mean age=60.8 ± 7.9 years) underwent ^{129}Xe MRI with multiple doses of enriched ^{129}Xe (86%), polarized to 7-10% (1-L batches) and 10-15% (300-ml batches) by two polarizers (Polarean, Inc, Durham, NC). Subjects underwent ^{129}Xe ventilation MRI in the following order: 1-L GRE, 1-L 3D-radial, 300-ml GRE, and 300-ml 3D-radial. GRE acquisition parameters were: FOV=40/36cm (1L/300ml), 12.5mm slice, matrix=128×128, (1L) or 64×64×14 (300ml), BW=8.3 kHz, α=7-10°, TR/TE=8.1/1.9 ms. For 3D-radial imaging, parameters were: FOV=36/48cm (1L/300ml), matrix=64×64×64, rays=4601, TR/TE=3.3/0.376ms,, BW=15.63kHz, ^{129}Xe GRE image analysis relied on defining the thoracic cavity using a breath-hold ^{1}H FIESTA (SSFP) image with FOV=40cm, 12.5mm slice, matrix=192×192, α=45°, TR/TE=2.8/1.2ms, BW=125kHz. ^{129}Xe radial image analysis used a free-breathing 3D-radial scan of the thoracic cavity with parameters FOV=36cm, matrix=128×128×128, TR/TE=3/0.24ms, rays=80,001, BW=62.5kHz, α=15°. To constrain image analysis to the thoracic cavity, all ^{1}H images were registered to the gas-phase image using the Image Registration Toolkit[3]. The FIESTA images were registered to the GRE ^{129}Xe images using a multi-resolution affine transform. The free-breathing radial ^{1}H images were registered to the radial ^{129}Xe ventilation images first using a multi-resolution affine transform, followed by a non-rigid landmark based registration step. For all 4 ^{129}Xe image sets, region growing was used, as previously described[4] to generate ventilation defect maps from which ventilation defect percentages (VDP) were calculated . Also, ^{129}Xe ventilation image histograms were normalized to a scale of 0-1, and linear binning was applied with thresholds set at 15%, 50%, and 85% to calculate the volume of 4 different clusters - defects, hypointense, normal and hyperintense[5].

Results: Images were successfully obtained for all the subjects scanned using both dose volumes and pulse sequences. The figure below shows representative images, defect maps, and binning maps from all the ^{129}Xe scans obtained in a 75 yr. old volunteer. As seen in both types of maps, defects are seen in the lung periphery in both the 300-ml and 1-L scans using both sequences. Both the region growing algorithm used for the defect percentages and the binning approach reflect the visually perceived aspects of the images. The VDP for all subjects using the GRE sequence was 9.1±0.014% (1-L) and 8.4±0.024% (300-ml). The VDP using the radial sequence was slightly lower 5.3±0.032% (1-L) and 6.2±0.041% (300-ml). Although, the binning algorithm showed comparable defect values of 10.9±0.023% (1-L) and 10.5±0.024% (300-ml) for the GRE sequence, it consistently returned lower defect percentages with the radial sequence (2.8±0.022 [1-L] and 3.8±0.025% [300-ml]).

Discussion and Conclusion: This preliminary analysis has shown that the defect volumes obtained with 300-ml of ^{129}Xe is comparable to that obtained with a full liter. The binning method provides an elegant way to quantify defects and has the capability of highlighting subtle features of ventilation that could be missed with the binary classification scheme employed for the ventilation defect map. However, the lower resolution of the radial sequence caused defects to be underestimated with both the VDP and binning method. Note, the higher defect percentage seen with both the dose volumes in the GRE sequence could result from greater susceptibility induced losses caused by longer TE. This binning method is a precursor to the more robust k-means clustering algorithm[5], which should minimize any user-induced bias in the classification. On the whole, the similar results seen with the two volumes provide encouragement for a short, yet quantitative xenon exam.

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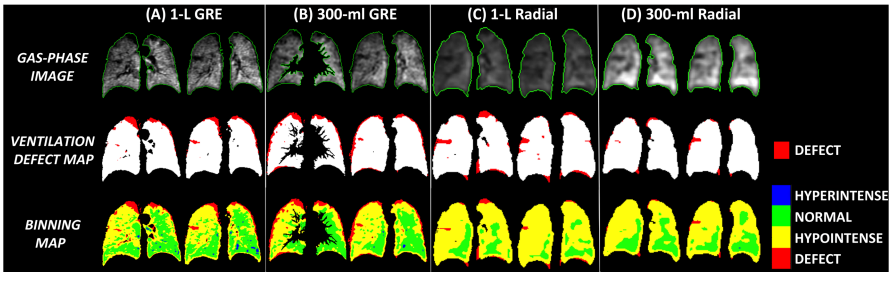

Figure: Ventilation images and associated defect and binning maps for 75 yr old subject. The defect percentages for the 1-L GRE images (A and B) obtained using both analysis methods are 9.4% (VDP) and 10.5% (binning), and are similar for the 300-ml images (8.4% VDP, 10.4% binning). The radial images (C and D) show a show lower defect percentages for the 1-L scan (5% VDP, 2.6% binning), and these results are unchanged and low in the 300-ml scan (6.2% VDP, 3.4% binning)