

Quantitative Scoring of Hyperpolarized ^{129}Xe Ventilation Imaging: Correlation with Pulmonary Function Testing and Age

B. Driehuys^{1,2}, Z. I. Cleveland^{1,2}, J. Nouis^{1,2}, S. S. Kaushik^{2,3}, G. P. Cofer², S. Jimenez-Martinez¹, J. Wolber⁴, M. Kraft⁵, and H. P. McAdams¹

¹Department of Radiology, Duke University, Durham, NC, United States, ²Center for in vivo Microscopy, Duke University, ³Biomedical Engineering, Duke University, ⁴GE Healthcare, ⁵Pulmonary and Critical Care Medicine, Duke University

Introduction: We have recently completed a phase I clinical trial enrolling 44 subjects to undergo hyperpolarized (HP) ^{129}Xe MRI. We have already reported on apparent diffusion coefficient (ADC) imaging [1], dissolved-phase ^{129}Xe imaging [2], and a detailed safety assessment [3]. Here we report on quantitative analysis of ^{129}Xe ventilation imaging using a simple reader-based scoring system [4]. With this approach we show that xenon ventilation scores correlate with pulmonary function tests and readily separate subjects with chronic obstructive pulmonary disease (COPD) from age-matched controls. Moreover, in the healthy subject population, we show that defects scores correlate significantly with age.

Methods: The subject population consisted of 24 healthy volunteers (HV, age 32.2 ± 11.4 yr), 10 age-matched controls (AMC, age 62.9 ± 7.8 yr) and 10 subjects with COPD (age 69.5 ± 6.4 yr). ^{129}Xe gas (83% isotopically enriched) was polarized in 1-liter doses to 6-10% by Rb vapor spin exchange using a prototype commercial polarizer (GE Healthcare, Durham, NC). Studies were conducted under the GE Healthcare IND and were approved by the Institution's IRB. ^{129}Xe ventilation images were acquired on a 1.5 T GE scanner (EXCITE 14M5) using FOV=40x(28-40) cm, matrix = 128x(90-128), slice thickness=15 mm, TR/TE = 7.9/1.9 ms, α = 5-7°, and BW=8kHz during an 8-12 sec breath-hold. Images were scored by two thoracic radiologists with more than 15 and 7 years of experience using a system similar to that proposed by Donnelly [4]. The left and right lung were divided into 3 regions (apical, middle, and basal) and the extent of ventilation defects was scored as: 0 = no defects, 1 = 0 to 25%, 2 = 25 to 50%, 3 = 50 to 75%, and 4 = 75 to 100%. These scores were summed over all regions to obtain a final ventilation defect score (VDS) for each subject of 0 – 24.

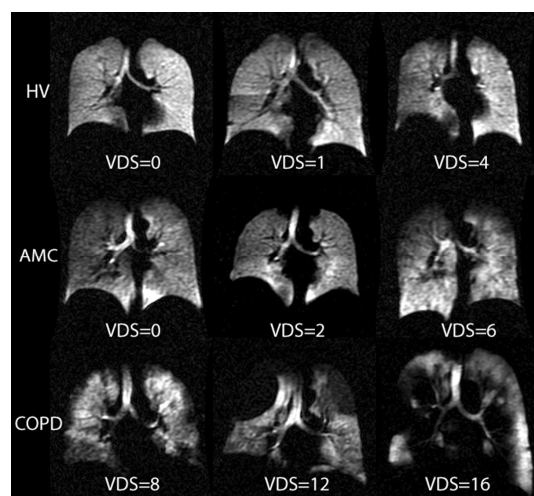


Fig 1: Representative central image slices acquired from 3 HV, 3 AMC, and 3 COPD subjects. Also shown are the ventilation defect scores (VDS) for that subject determined by evaluating all slices.

healthy elderly volunteers [7]. However, that study found that, unlike elderly subjects, healthy middle-aged (44 ± 10 yr) volunteers exhibited no defects. By contrast, our study using ^{129}Xe MRI found defects in all age groups and indeed a significant correlation with age. This may suggest that ^{129}Xe with its 4.5-fold greater resistance to flow [8], highlights modest airflow obstruction more effectively than ^3He .

Acknowledgements: GE Healthcare, Philip Morris External Research Fund, Center for in vivo Microscopy, P41 RR005959

References: 1. S. S. Kaushik *et al.*, *Magn. Reson. Med.* (in press). 2. Z. I. Cleveland *et al.*, *PLoS ONE* **5**, e12192 (08/16, 2010). 3. B. Driehuys *et al.*, *Radiology* (Submitted). 4. L. F. Donnelly *et al.*, *Radiology* **212**, 885 (1999/09, 1999). 5. L. Mathew *et al.*, *Eur. J. Radiol.* (In Press). 6. N. Woodhouse *et al.*, *J. Magn. Reson. Imaging* **21**, 365 (Apr, 2005). 7. G. Parraga *et al.*, *Acad. Radiol.* **15**, 776 (2008). 8. J. M. Drazen *et al.*, *J. Appl. Physiol.* **41**, 388 (1976).

Results: Ventilation images were successfully obtained in all 44 subjects. As shown in Fig 1, ventilation defects were noted in all subject groups. Defects were least frequent in the younger HV group ($\text{VDS}=0.78 \pm 1.24$), more frequent in the older AMC group ($\text{VDS}=2.90 \pm 2.23$), and occurred with greatest frequency in the COPD group ($\text{VDS}=10.50 \pm 3.21$). The defect scores were significantly different between all groups ($p < 0.001$). As shown in Fig 2, defect scores also showed a strong negative correlation ($r = -0.79$) with FEV1 (% predicted), which was similar to that observed with other pulmonary function metrics (not shown). Fig 2 also shows that within the normal subject groups (HV and AMC), the ventilation defect scores correlated significantly with subject age ($r = 0.61$).

Discussion and Conclusions: This relatively simple scoring system showed a correlation of ^{129}Xe VDS with FEV1% that was stronger than recently reported in a COPD cohort for ^3He ventilation defect volume ($R^2 = 0.34$) [5]. Our observed correlation was of similar magnitude to the correlation of ^3He ventilation percentage with FEV1/FVC% ($r = 0.72$) reported in smokers and non-smokers [6]. The finding of ventilation defects correlating with age is supported by the work of Parraga *et al.* showing defects on ^3He MRI in

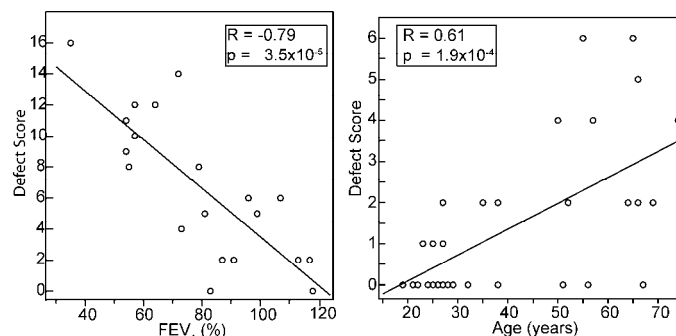


Fig 2: Correlations of ventilation defect score with FEV1 and age