

# Exploring Ventilation and Perfusion Matching in COPD with $^3\text{He}$ Ventilation and DCE $^1\text{H}$ Perfusion MRI

H. Marshall<sup>1</sup>, M. H. Deppe<sup>1</sup>, J. Parra Robles<sup>1</sup>, S. R. Parnell<sup>1</sup>, R. H. Ireland<sup>1</sup>, D. Capener<sup>1</sup>, S. Hillis<sup>1</sup>, S. Rajaram<sup>1</sup>, C. Billings<sup>2</sup>, D. A. Lipson<sup>3</sup>, R. Lawson<sup>2</sup>, and J. M. Wild<sup>1</sup>

<sup>1</sup>Academic Radiology, University of Sheffield, Sheffield, South Yorkshire, United Kingdom, <sup>2</sup>Respiratory Medicine, University of Sheffield, Sheffield, South Yorkshire, United Kingdom, <sup>3</sup>GlaxoSmithKline, King of Prussia, PA, United States

**Introduction:** The matching of ventilation and perfusion in the lungs is essential for gas exchange, and measurement of the regional ventilation and perfusion (V/Q) distribution is desirable for the assessment of lung function in chronic obstructive pulmonary disease (COPD). Previous preliminary work with  $^3\text{He}$  ventilation and  $^1\text{H}$  perfusion imaging in healthy volunteers, pulmonary embolism and lung transplant patients [1], and in asthmatics [2] showed promising results.  $^3\text{He}$  ventilation and matched perfusion imaging in animal models of pulmonary disease has been performed by several groups, e.g. [3-7]. COPD is characterised by abnormalities of air flow and gas exchange which may change over time in regions of reversible airflow obstruction and in response to different treatments. Here the combined use of  $^3\text{He}$  ventilation and dynamic contrast enhanced (DCE)  $^1\text{H}$  perfusion MRI was explored to provide measures of regional V/Q distribution in COPD patients.

**Methods:** Four COPD patients (inclusion criteria: post-bronchodilator forced expiratory volume in 1s (FEV1) / forced vital capacity (FVC) < 0.7, post-bronchodilator FEV1  $\geq$  30% and  $\leq$  80% of predicted, cigarette smoking history of  $\geq$  10 pack years, resting pulse oximeter oxygen saturation (SpO<sub>2</sub>) of > 90% on room air) were scanned using a 1.5T MRI system (GE HDx, Milwaukee, WI). Patients were positioned in a  $^3\text{He}$  transmit-receive vest coil (Medical Advances, Milwaukee, WI) and  $^3\text{He}$  ventilation images were acquired at breath-hold after the inhalation of 300ml  $^3\text{He}$  and 700ml N<sub>2</sub> (sequence parameters: 2D SPGR, coronal, FOV=35cm<sup>2</sup>, matrix=128<sup>2</sup>, 20x10mm slices,  $\theta$ =7°, BW=±31kHz, TE=1.1ms, TR=3.6ms,  $^3\text{He}$  polarisation ~25%). The  $^1\text{H}$  body coil was used to image the same slices after inhalation of 1L air to recreate the  $^3\text{He}$  breath-hold position (parameters: 2D bSSFP, matrix=256x192,  $\theta$ =50°, BW=±125kHz, TE=0.8ms, TR=2.8ms). Patients were repositioned into an 8-element  $^1\text{H}$  cardiac coil (GE, Milwaukee, WI) and imaged with the same bSSFP sequence at inhalation of 1L air for anatomical matching purposes. Perfusion data were acquired at inspiratory breath-hold on injection of a dose of Gadovist (Schering, Berlin) (parameters: 3D fast SPGR, TRICKS, SENSE R=2, coronal, FOV=48cm<sup>2</sup>, matrix=80x200, 22x10mm slices,  $\theta$ =30°, BW=±125kHz, TE=0.8ms, TR=2.3ms, 36 temporal phases, 2 phases per second, 0.05ml/kg of Gadovist at 4ml/s, 20ml saline flush at 4ml/s). Perfusion images were made by subtracting the signal intensity of the first temporal phase from the peak signal intensity of the time course pixel by pixel in Matlab (Natick, MA). Three slices (posterior, central and anterior) were chosen from each patient dataset for preliminary analysis. Ventilation and perfusion images were visually compared on a slice by slice basis, and superimposed together to make V/Q overlay images. The ventilated and perfused lung volumes were calculated, using image intensity threshold methods similar to that described in [8], as a percentage of total lung volume which was measured by manual segmentation of the anatomical images and excluded major airways and vessels.

**Results and Discussion:** Ventilation and perfusion images from patients 4 and 3 are shown in figs 1 and 2 respectively. Regions of ventilation and perfusion were generally well-matched, but there were some areas of mismatch (e.g. white circles) where the tissue was perfused but not ventilated or vice versa. The posterior slice in fig 1 displays a large region of unventilated and unperfused tissue in the upper right lung which is matched by an area of low signal intensity in the  $^1\text{H}$  bSSFP image indicating total tissue destruction. Preliminary registration results using a mutual information algorithm are shown in fig 3 for the posterior slice from patient 4 (fig 1, top row). Ventilated and perfused volumes as a percentage of total volume for the posterior, central and anterior slices from each patient are shown in fig 4. Future work will involve the registration of  $^3\text{He}$  ventilation and  $^1\text{H}$  perfusion datasets to improve the visualisation of V/Q matching and allow a union intersection measure of V/Q matched lung tissue.

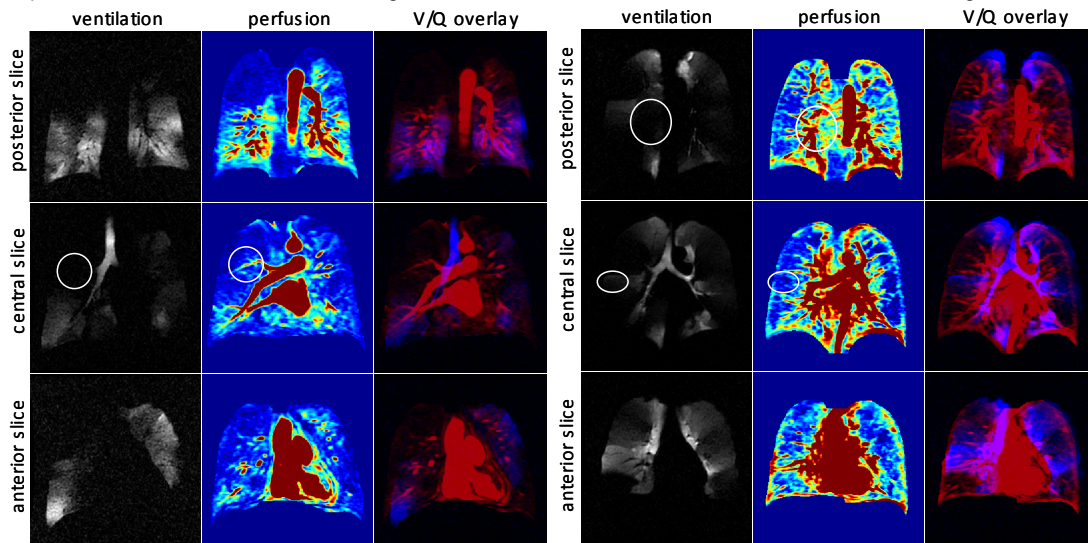


Fig 1; ventilation (left), perfusion (middle) and ventilation-perfusion overlay (right, ventilation blue, perfusion red) images of patient 4. Posterior (top), central (middle) and anterior (bottom) slices are shown. The white circle highlights a perfused area which is not ventilated.

Fig 2; ventilation (left), perfusion (middle) and ventilation-perfusion overlay (right, ventilation blue, perfusion red) images of patient 3. Posterior (top), central (middle) and anterior (bottom) slices are shown. The white circles highlight examples of ventilation-perfusion mismatch.

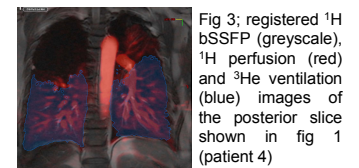


Fig 3; registered  $^1\text{H}$  bSSFP (grayscale),  $^1\text{H}$  perfusion (red) and  $^3\text{He}$  ventilation (blue) images of the posterior slice shown in fig 1 (patient 4)

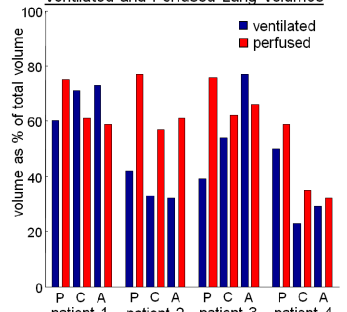


Fig 4; ventilation (blue) and perfusion (red) volumes as a percentage of total volume for each slice (posterior (P), central (C), anterior (A)) from each patient.

**Conclusions:**  $^3\text{He}$  ventilation and DCE  $^1\text{H}$  perfusion MRI provide good visualisation of regional V/Q distributions in COPD patients, allowing the detection of areas of matched and unmatched V/Q. These methods may provide a means of regional quantitative therapy response evaluation in COPD.

**Acknowledgements:** Funded by GlaxoSmithKline (RES111175) and UK EPSRC. Acknowledgement of GE for polariser support.

**References:** [1] Lipson et al, MRM 47:1073-1076 (2002); [2] Panth et al, proc ISMRM 2004 764; [3] Cremlieux et al, MRM 41:654-648 (1999); [4] Zheng et al, MRM 47:433-438 (2002); [5] Rizi et al, MRM 52:65-72 (2004); [6] Dimitrov et al, JMRI 21:149-155 (2005); [7] Mistry et al, MRM 63:728-735; [8] Woodhouse et al, JMRI 21:365-369 (2005)