# Direct Imaging of Delayed and Collateral Ventilation in COPD using Hyperpolarised $^3$He MRI

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**Introduction:** Collateral ventilation [1] is an important mechanism in the patho-physiology and treatment of [2] Chronic Obstructive Pulmonary Disease (COPD), but limited observations of it *in vivo* have been demonstrated. Current techniques capable of imaging collateral ventilation [3, 4] require monitoring over multiple breathing cycles and use ionising radiation. Long-range diffusion measurements with hyperpolarised $^3$He MRI [5] are potentially sensitive to collateral ventilation, but are indirect and can only imply that collateral ventilation is taking place.

Here delayed filling related to collateral ventilation was imaged over the period of a single breath-hold in COPD, using hyperpolarised $^3$He MRI. Other examples of delayed ventilation, which may be due to mechanisms such as partial obstruction, increased peripheral airways resistance and air trapping, were also observed.

**Methods:** Ten patients with moderate to severe COPD as defined by GOLD guidelines were scanned using a 1.5T whole body MRI system (GE HDx, Milwaukee, WI). Patients were positioned in a $^3$He transmit-receive vest coil (Clinical MR Solutions, USA). A mix of 200ml hyperpolarised $^3$He (25% polarisation) and 800ml $N_2$ was inhaled, and $^3$He MR images were acquired using a 3D coronal SPGR sequence with full lung coverage, $\theta$=1° and voxel size=5.5x10.9x20mm. The 3D volume was acquired at six time-points during a single breathold.

**Results:** Figure 1 shows images of two initially non-ventilated defects which gradually filled with gas over the time-course of the breathold. Hyperpolarised $^3$He MR signal is non-renewable and diminishes over time due to both the imaging procedure and natural $T_1$ relaxation processes due to the presence of oxygen [6]. In normally ventilated regions of the lung this expected signal decay is observed and has been used to infer lung oxygen partial pressure [7]. However, in the regions indicated with arrows the signal *increases* over time, with a progressive influx of gas from the edge of the defects towards the centre. The gas filling pattern is not consistent with the defects being ventilated via their feeding bronchi, suggesting that gas is entering via collateral pathways at the defect edges.

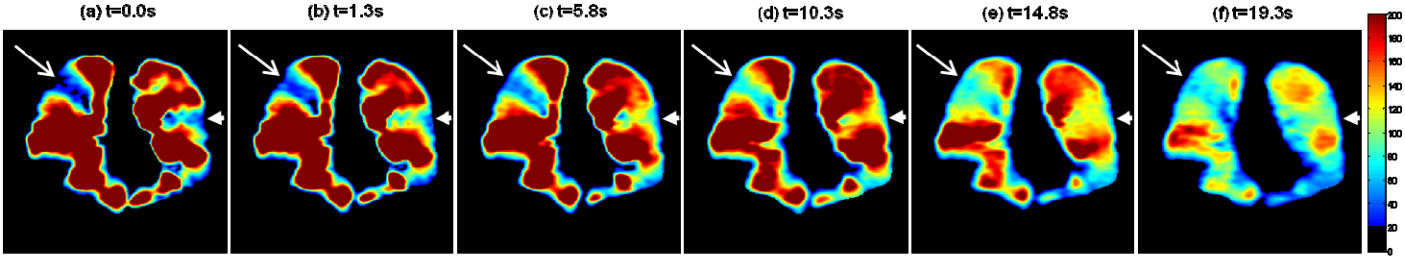


Figure 1: Images tracking collateral ventilation in a COPD patient (a-f), all displayed with the same colour-scale.

An example of delayed-filling of a peripheral ventilation defect is shown in figure 2. The slow-filling of the defect, with a front of gas progressing slowly towards the lung edge, may be due to increased resistance to air-flow in the peripheral airways. Ventilation defects with delayed-filling were observed in eight of the ten patients scanned. These examples varied in defect size, number and fill-rate from the strongest case (fig 1) to much more subtle effects.

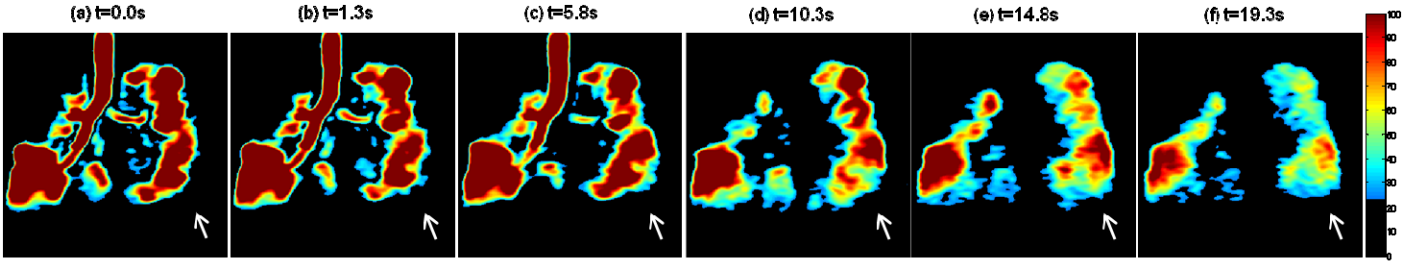


Figure 2: Images showing delayed-filling of a peripheral ventilation defect (a-f), all displayed with the same colour-scale.

**Discussion:** High-resolution $^3$He ventilation images which were acquired during the same scanning session showed no information about the delayed wash-in of gas, with slow-filling defects appearing as signal voids. $^3$He in air is more diffusive than xenon in air or pure air alone, so it is likely to show a faster and potentially amplified effect, allowing delayed/collateral ventilation to be visualised directly over the period of a single breath-hold.

**Conclusions:** A method is demonstrated for direct imaging of delayed ventilation within a single breath-hold, which is able to visualise what we believe to be collateral ventilation in COPD.

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**References:** [1] Hogg et al, J Clin Invest 48(3):421-31 (1969); [2] Cetti et al, Thorax 61(5):371-73 (2006); [3] Salanitri et al, Intern Med J 35(2):97-103 (2005); [4] Chae et al, Radiology 255(3):790-98 (2010); [5] Owers-Bradley et al, JMRI 17(1):142-46 (2003); [6] Wild et al, Magn Reson Med 53:1055-1064 (2005); [7] Deninger et al, JMR 141:207-16 (1999).