Observation of gravitational dependence of regional fractional ventilation in human lungs with 2D and 3D multi-breath washout imaging of ^{3}He and ^{129}Xe

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Introduction: Multiple-breath inert gas washout (MBW) is a pulmonary function test that has been shown to be sensitive to ventilation heterogeneity in early stages of lung disease [1]. Whilst measuring the concentration of gas at the mouth returns a global parameter, regional ventilation parameters can be acquired with hyperpolarised gas MRI. Regional fractional ventilation (*r* = % gas exchanged per breath) has been demonstrated with HP ^{3}He in mechanically ventilated animal experiments [2,3]. Monitoring of MBW with ^{3}He was demonstrated in free breathing following imaging of lung ventilation using a single dose of gas [4], this approach was extended to a 2D ^{3}He washout imaging sequence capable of producing maps of *r* [5]. In this work, 2D and 3D images of gas washout in free breathing humans were obtained with single inhaled doses of HP ^{3}He and ^{129}Xe, which allowed the assessment of gravitational regional fractional ventilation effects.

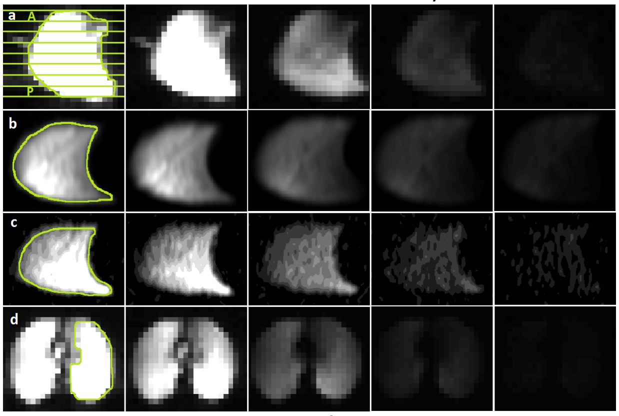

Figure 1: The first 5 images of (a) ^{3}He 3D sagittal projection (b) ^{3}He 2D (c) ^{129}Xe 2D (d) ^{3}He 3D axial projection.

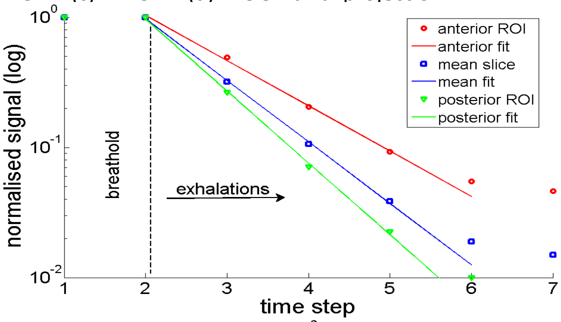

Figure 2: Signal evolution of 3D ^{3}He in different lung regions, corrected for RF depolarization and T_1 decay

Materials and Methods: Imaging was performed in supine position on a GE HDx 1.5 T scanner using quadrature ^{3}He and ^{129}Xe flex coils (CMRS). A multiple phase 2D/3D fast SPGR sequence with a FOV of (38x38) cm^{2} was used for MBW imaging. After each breathold data acquisition there was a 4 sec gap. Between the first and second image the healthy volunteer (30yr, f, 60 kg) held her breath, and afterwards was encouraged to exhale and inhale the tidal volume between each subsequent imaging acquisition made at subsequent breatholds until the signal was fully decayed. The breathold was approximately 5 sec in the case of the 3D sequence and about 2 sec in the case of the 2D sequence. For the 2D sequence, two sagittal slices, one for each lung, with a matrix of 64x32 were acquired. For the 3D volume sequence a 32x32x32 matrix was acquired. The flip angle was chosen around 1.5° for the 2D sequence and 1° for the 3D sequence. For the ^{3}He experiments, 1 *l* of a 1:4 mixture of HP ^{3}He (~ 20% polarisation) and N_2 was used, for the ^{129}Xe experiments the ratio of the 1 ℓ dose was 3:10 ^{129}Xe (~14% polarisation).

Results: Figure 1 shows the first five images of each experiment with the same windowing. The signal decay between the different phases in the washout time series was corrected for T_1 decay and RF depolarisation using the images from the first and second acquisition, which were acquired at breathold (assuming constant T_1). The decay of signal due to washout was then fitted to a mono-exponential curve (see Figure 2). From the slope of the exponential decay the regional fractional ventilation parameter *r* was calculated. To evaluate the gravitational effects of regional ventilation for each acquisition, a ROI was manually selected (see Figure 1). To compare regional ventilation of different sections, it was assumed that the lung size remained the same for each experiment and time phase. No additional image registration was performed. The ROI was divided into horizontal stripes (as shown in the first image in Figure 1) of equal size according to gravitational position from A-P, relative to the lowest position of the lung. Each level of the ROI was averaged and *r* was evaluated. In Figure 3 the regional ventilation parameter *r* is plotted against the position within the lung. The circles represent a horizontal stripe ROI, from anterior to posterior; the line is a linear fit to all the points.

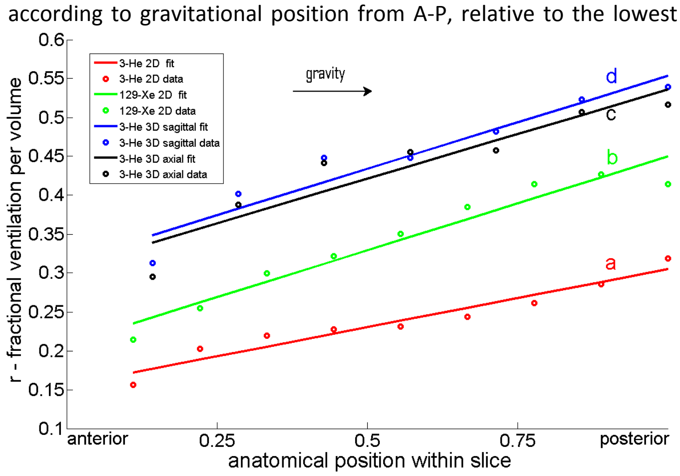

Figure 1: Fractional ventilation r dependence on location with gradients: (a) 0.15 (b) 0.24 (c) 0.23 (d) 0.23.

Discussion: Gravitational effects in the washout of hyperpolarised ^{3}He and ^{129}Xe with 2D and 3D imaging are demonstrated in this work. The three curves in Figure 3 show the gravitational effects in a volunteer. Regional ventilation is higher in dependent than in non-dependent regions, as expected [3, 4]. The gravitational trend seen in fractional ventilation is observed irrespective of both the imaging sequence and the type of gas being used. However the measured fractional ventilation values, *r,* does depend upon the gas used and on the sequence. The offset in *r* values between curves is likely to be due to different respirational volumes after the period of apnoea which is dictated by the duration of the imaging sequence used. The fact that the 3D dataset seems to have a higher *r*, might in part be caused by an increased inspiratory effort after the longer breathold due to the longer imaging sequence time compared to 2D. This will be reduced in future work with the use of accelerated 3D sequences [6,7]. The difference in ^{3}He and ^{129}Xe density may also play a role in different washout rates and this warrants further investigation.

References: [1] Thorax. 59(12): 1068-732004(2004); [2] Mag. Reson. Med. 48:223-232 (2002); [3] Magn. Reson. Med. 2010 ;63(1):137-5; [4] Mag. Reson. Med. 65(4): 1075-83(2011); [5] Proc. ISMRM 2011 p 910; [6] Magn Reson Med. 2011 May 13. doi: 10.1002/mrm.22962. [7] Magn Reson Med. 2010 ;63(4):1059-69.

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