V/Q Imaging of the Human Lung Measured at 1.5T by a Single Acquisition Technique and Tested by the Gravitational Effect

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Purpose: Methods for non-invasive, non-contrast, quantitative assessment of both lung ventilation and perfusion have previously been published seperatly[1,2]. We now combine these methods and obtain non-invasive, quantitative V/Q-maps. To evaluate the accuracy of these maps, the gravitational effect in eight healthy volunteers is investigated.

Method: Registered lung images at inspiration and expiration have successfully been combined to calculate a surrogate for ventilation[1]. The hypothesis behind the idea is based on a two compartment model where the lung consists only of a fixed volume of lung tissue and variable volume of air. This means that during inspiration, when the lung density is reduced, air has replaced lung tissue. Then, if the relative decrease in lung density is known, calculation of the relative increase of air is possible. This was first done in MR by Zapke et al[1] and we use a slightly modified version of their ventilation equation:

$$V = (\hat{S}_{exp} - \hat{S}_{insp}) / \hat{S}_{exp}$$

where $\hat{S}_{exp}$ is the 85 percentile of the time dependent image signal (corresponding to expiration), $\hat{S}_{insp}$ the 15 percentile of the time dependent image signal (corresponding to inspiration). This was done to reduce noise.

It was recently shown that the Fourier Decomposition method[3], which uses time series analysis to separate the cardiac and respiratory signal, can yield quantitative lung perfusion images[2]. Assuming the separated perfusion signal originates from blood only, the blood volume in each pixel can be calculated by comparing its signal with the signal in a region with 100% blood (ex. the aorta). The perfusion formula is given by Kjørstad et al[2]:

$$Q = S_{pixel} / (S_{blood} \cdot 2 \cdot T)$$

where S_{pixel} is the signal in a normal lung pixel, S_{blood} the signal in a pixel with 100% blood and T the inflow time.

Free breathing dynamic images were acquired from eight healthy volunteers using a 2D TrueFISP sequence on a 1.5T scanner (Magnetom Avanto, Siemens Healthcare, Erlangen, Germany) with FOV = 450x450 mm^2, matrix = 128x128, slice thickness = 15mm, TR/TE = 1.9/0.8 ms, FA = 75°.

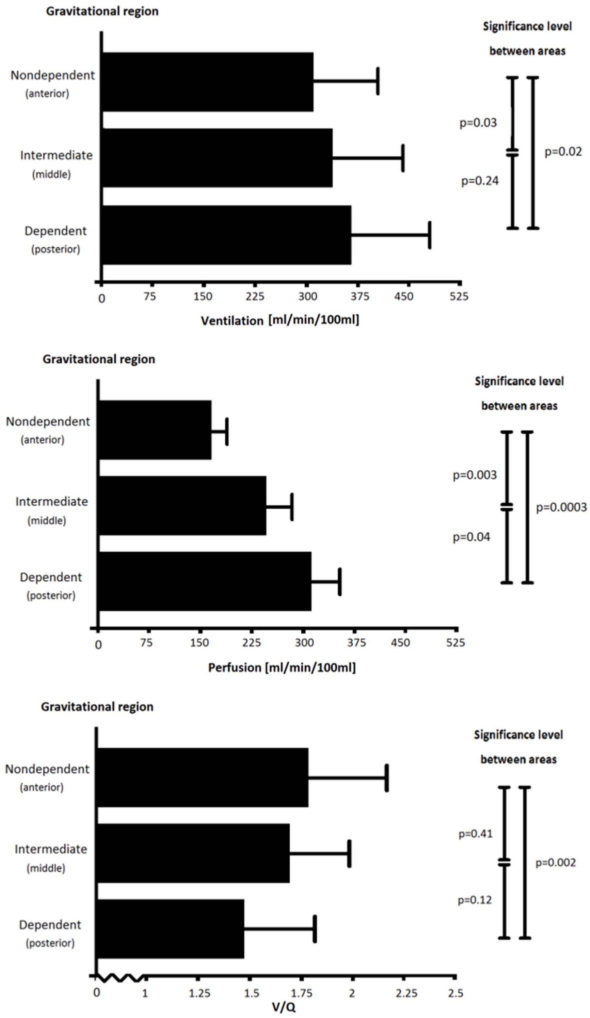

Figure 1. The gravitational effect in the ventilation (top), perfusion (middle) and V/Q (bottom) images. Values are average plus standard deviation from all eight subjects. The significance level between areas is shown on the right.

Results: The lungs were manually segmented and automatically divided into three sections from anterior to posterior. The mean value of each region was calculated. The average values for the ventilation, perfusion and V/Q-ratio in each region can be seen in Figure 1. The gravitational slope was then calculated using six gravitational regions and a linear fit. The slopes were then converted to percentage per cm, based on the mean value and height of the lung. The ventilation was found to have a 1.3$\pm$1.3% increase per cm when going from anterior to posterior, the perfusion had a 3.7$\pm$1.4% increase per cm and the V/Q a 1.6$\pm$0.8% decrease per cm. Image from one of the subjects can be seen in Figure 2.

Discussion: All three parameters show a significant ($p<0.05$) difference between the least and most dependent region of the lung. As expected from literature[4], the ventilation and perfusion increases while the V/Q decreases when going from anterior to posterior. This is due to the perfusion slope being higher than the ventilation. Our calculated perfusion slope is in accordance with other studies[4,5], while the ventilation is somewhat lower[4], which also leads to a higher V/Q slope.

Conclusion: We have demonstrated that non-invasive, non-contrast V/Q imaging is achievable, with the resulting maps showing the expected values and behavior with respect to gravity. This further strengthens the ventilation and perfusion methods claim of accuracy.

References: [1]: Zapke, Respir Res 2006, 7, p. 106; [2]: Kjørstad, Magn Reson Med 2013, *in print*; [3]: Bauman, Magn Reson Med 2009, 62(3):656-64; [4]: Musch, J Appl Physiol 2002, 93(5), pp. 1841–1851; [5]: Hopkins, J Appl Physiol 2007, 103(1), pp. 240–248;
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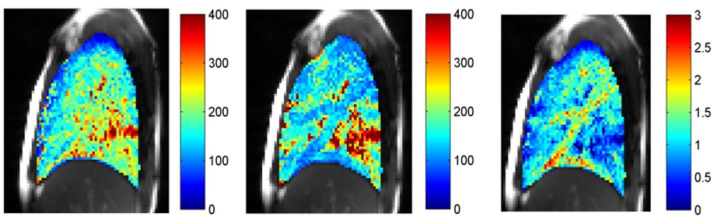

Figure 2. Ventilation (left), perfusion (middle) and V/Q (right) maps from 26 year old healthy male.