Comparison of Calculated Specific Ventilation using the 'Wash-in' and 'Wash-out' Hyperpolarized ^{3}He MRI Techniques

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INTRODUCTION: It has been previously demonstrated that hyperpolarized (HP) ^{3}He MRI can be used to construct regional specific ventilation maps by imaging HP signal build up, by delivering several HP breaths, each followed by a breath hold for image acquisition. The construction of a specific ventilation map by this 'wash-in' method usually requires 2-3L of HP ^{3}He. More recently, it was shown [2] that a similar regional fractional ventilation map could be constructed by fitting the signal decay after only one inhalation of HP gas (less than 1L of ^{3}He). In this study, we compare the regional specific ventilation maps generated by both the 'wash-in' and 'wash-out' methods to determine the robustness of the 'wash-out' method compared to the 'wash-in' method.

METHODS: 3 subjects were imaged using the hybrid multibreath imaging technique, demonstrated previously [1]. Briefly, a custom built gas delivery device was used to deliver normoxic mixture of HP 3He:N2:O2 (3:1:1) based on the subjects' total lung capacity (12% TLC) in the first 7 breath holds of a multi-breath regime. Hyperpolarized ^{3}He imaging was performed during a sequence of 13 breath holds (6 short (~1s) wash-in breath holds, followed by a 12s long breath hold, followed by a 6 short(~1s) wash-out breath holds). Patients were scanned using a 1.5T Sonata (Siemens Healthcare) MRI scanner using an 8-channel chest coil (Stark Contrast) and GRAPPA ~2x acceleration. The common imaging parameters between all the imaging were as follows: 6×20-mm coronal slices, 4-mm spacing, ~8.3×8.3mm2 spatial resolution, matrix = 64x48px, FOV=400×300mm2, nominal α=~5°. The 'wash-in' specific ventilation maps were constructed from the slice selective GRE images acquired in the first 6 breath holds (TR/TE=3.6/3.3ms) during signal buildup. The 'wash-out' specific ventilation maps were constructed from the slice selective GRE images acquired in the last 6 breath holds (TR/TE=3.6/3.3ms) during signal decay. However, before constructing the ventilation maps, a flip angle map was generated by simultaneous pAO2-ADC-imaging during the 12s breath hold (slice selective GRE, TR/TE=17.8/5.7ms for pO2; diffusion-weighted, TR/TE=8.9/5.7ms for ADC). The wash-in fractional ventilation map was computed by fitting the signal buildup in multiple back-to-back breaths to a dynamic recursive model, whereas the wash-out fractional ventilation map was computed by fitting the signal decay to an exponential function in back-to-back breaths. The two models were then correlated with each other and a best-fit coefficient was derived.

RESULTS: Figure 1 shows a representative specific ventilation map for both the 'wash-in' method (top) constructed via signal buildup of 6 HP helium breaths, and the 'wash-out' method (bottom) constructed via the signal decay of the inhaled gas. The six coronal slices are from the most anterior (leftmost) to posterior slice. Figure 2 shows a scatter plot of each corresponding pixel from all six slices of the wash-in and wash-out ventilation maps (R = 0.62). The average specific ventilation of the 3 subjects from the 'wash-in' map, and 'wash-out' map was 0.35±.04, and 0.20±.09 respectively.

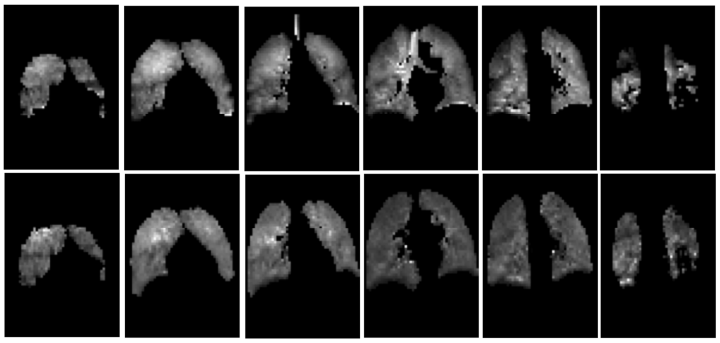

Figure 1: Ventilation maps derives from the 'wash-in' method (top) and 'wash-out' method (bottom)

DISCUSSION: The two methods show a very similar profile in their ventilation maps (Figure 1), which suggests that both techniques could potentially be used to build specific ventilation maps. The values in the 'wash-out' method seem slightly lower, with a greater variance, which might be due the lower SNR, from the general signal decay, resulting in a less robust fit, as well as increased T1 relaxation due to the fresh oxygen intake. The 'wash-out' derived ventilation map is not oxygen corrected, which also lowers the calculated SV values. The correlation plot shows a very strong correlation, which suggests that the 'wash-out' method is a good substitute for the 'wash-in method'. Although our hybrid multibreath imaging technique is used to acquire multiple different regional parameters, if the only parameter of interest is the regional specific ventilation map, the 'wash-out' approach might provide similar results to the 'wash-in' method, whilst using less hyperpolarized gas.

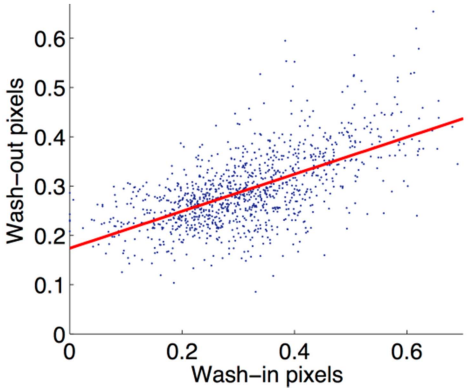

Figure 2: Correlation plot of SV values on a pixel-to-pixel basis from one representative subject

[1] Emami, et al., ISMRM 2012 [2] Horn, et al. ISMRM. #1470 (2013)