Multi nuclear 3D multiple breath washout imaging with ^{3}He and ^{129}Xe using a dual tuned coil

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Purpose: Multiple breath washout (MBW) as measured in the pulmonary function lab is a sensitive marker for early-stage lung disease [1]. MBW has been extended to provide regional information by measuring regional signal intensity decay during gas washout using hyperpolarised ^{3}He MRI [2,3]. ^{3}He and ^{129}Xe provide unique and complementary information about lung function due to their intrinsically different physico-chemical properties (e.g. diffusion coefficient). Hence measurement of their respective regional washout rates may be sensitive to different levels of severity and sub-types of obstructive airways disease [4,5]. This preliminary study presents a methodology for multiple breath washout imaging (MBW-I) with ^{129}Xe and ^{3}He using optimized steady-state (bSSFP) imaging and a dual-tuned radiofrequency coil, the latter mitigating the need to move the subject between acquisitions.

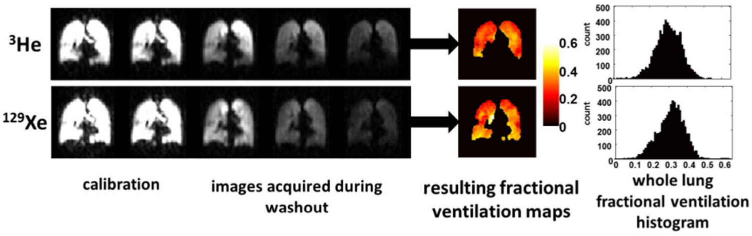

Figure 1: Multiple breath washout imaging with ^{129}Xe and ^{3}He of the same slice, resulting fractional ventilation maps I, and whole lung histograms. For the detials of image processing [3].

Methods: MBW-I was performed on 5 healthy volunteers using a GE HDx 1.5T MRI system and a home-built dual-tuned (48.62MHz (^{3}He) and 17.65MHz (^{129}Xe)) flexible transmit-receive coil [6]. Hyperpolarized ^{129}Xe (HP-Xe) and ^{3}He (HP-He) gas was polarized to ~60% and 25% with home-built [7] and commercial (MITI, Durham, NC) polarizers, respectively. For both gases, MBW-I was performed with an isotropic resolution of 1.2 cm^3 resulting in an in-plane matrix of 32x32 and 24 anterior-posterior slices, for a FOV=38cm^2. An optimized bSSFP sequence [8] was used for image acquisition, with the following parameters: **^{129}Xe**: TR/TE 2.9/0.9ms, BW = 16.1kHz, FA = 7° from a hard pulse, total gas dose = 600ml HP-Xe. **^{3}He**: TR/TE 1.4/0.4ms, BW = 166kHz, gas dose = 200ml HP-He. MBW-I of both gases was performed with the subject in the same position (since no coil change was required) and there was typically ~ 5 min elapsed between scans. **Data Analysis**: Fractional ventilation maps were masked with a mask to consider only mutual information for the comparison. Pearson's correlations and Bland-Altman analysis (B-A) was performed. B-A was used to calculated the %Mean Difference and % Standard deviation (% of average fractional ventilation).

Voxel-by-voxel comparison / Volunteer	V1	V2	V3	V4	V5
Ventilation heterogeneity (Xenon)	0.08	0.09	0.10	0.08	0.10
Ventilation heterogeneity (Helium)	0.11	0.08	0.10	0.07	0.10
Pearson's r (P<0.001)	0.51	0.46	0.27	0.53	0.66
%Mean Difference (Xe-He)	-30.0	+12.2	-22.3	+57.4	+2.9
%Standard deviation	39.8	35.8	50.1	53.2	26.9

Table 1: Overview results of voxel by voxel comparison from imaging ^{3}He and ^{129}Xe: ventilation heterogeneity, Pearson's correlation, and Bland-Altman analysis (%mean difference and %standard deviation).

Results and Discussion: 3D multiple breath washout imaging using HP-Xe has been shown for the first time. This has been made feasible by the efficient use of polarization afforded by bSSFP sequences and the recent improvements in ^{129}Xe polarization levels which has enabled high SNR images over up to 4 cycles of tidal breathing. An example dataset of both HP-He and HP-Xe acquisitions is shown in Figure 1 (volunteer 5) along with resulting fractional ventilation maps and whole-lung histograms (see [4] for details of analysis). Fractional ventilation maps for all subjects exhibited similar features and ventilation heterogeneity (VH, standard deviation from whole lung fractional ventilation histograms) values for both HP-He and HP-Xe data; in fact, the percentage standard deviation of fractional ventilation from the whole lung was similar in most subjects (Table 1). A voxel by voxel comparison of data from the two nuclei for each volunteer showed highly significant correlations (Pearson's r ~0.5), with the exception of volunteer 3. The high mean difference (%) in average fractional ventilations between the two nuclei suggests that a change in breathing pattern may be caused by the presence of a considerable amount (~15% inspired lung volume) of xenon, which is significantly denser and less diffusive than air or helium.

Conclusion: The feasibility of multi-nuclear MBW-I with ^{3}He and ^{129}Xe has been demonstrated for 5 healthy volunteers. Comparable functional information was derived from MBW-I datasets from both nuclei, with similar ventilation heterogeneity in most subjects exhibited by each, despite the intrinsically different physical properties of the two nuclei. In future work, it may be possible to identify sensitivity differences in MBW-I with ^{3}He and ^{129}Xe to different physiological processes symptomatic of obstructive lung disease such as the regional diffusion-convection front and focal air trapping, however further validation of the technique in a patient population is required to assess its applicability to this role.

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Acknowledgements: This work was funded by EU FP7 projects Pinet and AirPROM, and the National Institute of Health Research (NIHR).