Hyperpolarized xenon-129 3D-Chemical Shift Imaging of the lung in subjects with a history of smoke exposure

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Introduction:

Previous implementation of 3D Single Breath-hold Chemical Shift Imaging (SB-CSI) in humans has already been demonstrated for evaluating hyperpolarized xenon-129 (HP Xe-129) distribution in multiple lung compartments in healthy subjects and in subjects with cystic fibrosis [1]. Here, we report the application of this technique for assessing, in a regional manner, pulmonary ventilation and gas uptake-exchange in lung tissue and in the red blood cells (RBC) in smokers and second-hand smokers.

Methods:

Eight subjects enrolled in this study underwent 3D SB-CSI, (Table 1). Studies were approved by local IRB and all subjects gave informed consent to participate. All scans were done in a 1.5 T clinical MRI system (Avanto, Siemens Medical Solutions, United States) using a linear transmit/receive RF coil built in-house and tuned to the Xe-129 frequency. For each acquisition, 800±100 mL of HP Xe-129 gas (polarization ~35-50%; Xemed) was inhaled by the subject, followed by a breath-hold during the entire pulse-sequence acquisition. A matrix of 18x18x8 voxels, interpolated to 32x32x8 voxels, was positioned over the lungs, with a FOV of 320x320 mm^2, corresponding to an in-plane resolution of 17.8x17.8 mm^2. The slice thickness was 25 mm, TR was 27 msec and TE was 2.3 msec. The RF pulse was applied at the dissolved-phase frequency of HP Xe-129, approximately 200 ppm from that of HP Xe-129 gas in the airspaces. CSI post-processing was performed using the 3DiCSI (Qi Zhao, Columbia University) software package. The free-induction decay (FID) of each pixel from each slice was zero filled to 1024 points, filtered with a 50 Hz Lorentzian decaying function, Fourier Transformed and corrected for phase shifts. CSI maps of HP Xe-129 as gas in the airspaces and dissolved in lung tissue and in the RBC were generated for each slice of each subject. The ratio of xenon dissolved in the tissue to that dissolved in the RBC (tissue/RBC) was also obtained.

Table 1 – Subject data

Study no.	Age (y)	Sex	FEV_1, % pred.	FEV_1/FVC	Health status
1	19	F	104	0.84	Healthy
2	21	F	112	0.88	Healthy
3	21	F	106	0.85	Healthy
4	18	M	88	0.80	Healthy
5	18	F	119	0.87	Healthy
6	64	M	94	0.76	Second-Hand Smoker
7	40	M	83	0.69	Smoker
8	55	F	39	0.57	COPD/Smoker

Results:

Cigarette smoke exposed subjects had a higher tissue/RBC ratio than healthy subjects Figure 1, p=0.03. A strong correlation of the tissue/RBC ratio with FEV1/FVC (R=0.87) can also be seen in Figure 1, p=0.005. A more heterogeneous distribution of the tissue/RBC ratio within the lung was detected in the smokers as compared with healthy subjects (Figure 2).

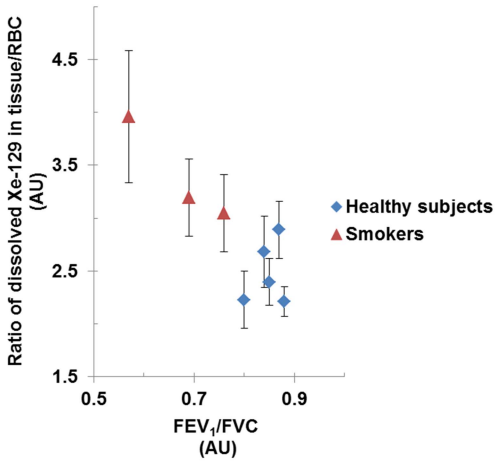

Figure 1 Mean tissue/RBC ratio for each subject, whose pulmonary function is expressed by a spirometry measurement (FEV_1/FVC).

Conclusions:

Assessment of regional signal from HP Xe-129 dissolved in pulmonary lung tissue and RBC by the 3D SB-CSI technique demonstrated an elevated tissue/RBC ratio in subjects exposed to smoke as compared with healthy subjects. Whether this is due a relatively reduced RBC fraction (e.g. reduced pulmonary capillary perfusion, or impaired gas exchange) or an increase in the tissue fraction (e.g. alveolar septal wall thickening from inflammation) or some combination of both could not be determined. However, with further refinement of this technique, it may be possible to elucidate the likely etiology of these differences. This technique has the potential to provide new insights into the pathobiology of various pulmonary diseases.

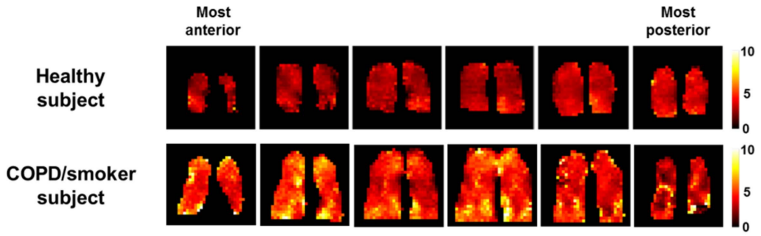

Figure 2 Coronal tissue/RBC ratio (AU) maps of a healthy subject (study #1) and a smoker with COPD (study #8).

References: [1] Reis et al., ISMRM, Melbourne, 2012 (abstract #5451).

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