Hyperpolarized Xe-129 CSI of the Human Lung: Preliminary Results from Healthy, Second-Hand Smoker and Cystic-Fibrosis Subjects

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Introduction:

Breath-hold 2D and 3D Chemical Shift Imaging (CSI) of the lung with hyperpolarized xenon-129 (Xe-129) has been previously demonstrated in animal models [1, 2] and optimized using principal component analysis (PCA) [3]. Here, we report the application and evaluation of this technique in the human lung. Preliminary evaluation of its application using a 3D-CSI approach in a normal subject, as well as in a second-hand smoker and in two subjects with cystic fibrosis, is presented. From the Xe-129 CSI data, we directly calculate image-maps reflecting the amount of Xe-129 in the airspaces (gas), and dissolved in the lung tissue (parenchyma/plasma), red-blood-cells (RBC), and other compartments, thus obtaining detailed spatial information regarding how Xe-129 is distributed in these multiple compartments and providing regional information about lung physiology.

Methods:

Table 1 – Subject data

Subject	Age (y)	Sex	FEV1 (%)	Health Status	CSI acquisition type
1	23	F	92	Healthy	2D projection
2	21	F	110	Healthy	2D projection
3	25	F	109	Healthy	2D projection
4	22	F	92	Healthy	2D projection
5	19	F	104	Healthy	3D multi-slice
6	64	M	94	Second-Hand Smoker	3D multi-slice
7	30	F	49	Cystic Fibrosis	3D multi-slice
8	19	F	55	Cystic Fibrosis	3D multi-slice

Eight subjects underwent Xe-129 2D- or 3D-CSI (Table 1). All scans were done in a 1.5 Tesla clinical system (Avanto, Siemens Medical Solutions) using a linear transmit/receive RF coil built in-house and tuned to the Xe-129 frequency. Isotopically enriched (~87%) Xe-129 was polarized to ~35-50% using a commercial prototype system (Xemed LLC, NH). For each acquisition, a single 250cc (2D-CSI) or 700cc (3D-CSI) volume of Xe-129 gas, mixed with oxygen and room air, was inhaled by the subject, followed by a breath-hold during the entire pulse-sequence acquisition. A matrix of 32x32 (2D) or 18x18x8 voxels (3D), interpolated to 256x256 voxels, was positioned over the lungs, with a FOV of ~320x320mm^2, corresponding to an in-plane resolution of 10x10mm^2 (2D) or 17.8x17.8 mm^2 (3D) and a slice thickness of 25 mm (3D). TR was 27 ms and TE was 2.3ms. For each excitation an RF pulse was applied at the frequency of dissolved-phase Xe-129, approximately 200 ppm from that for Xe-129 gas in the airspaces. The protocol was approved by our Institutional Review Board.

Xe-129 CSI post-processing was performed using the 3DiCSI (Qi Zhao, Columbia University, NY) and MATLAB (MathWorks, Natick, MA) software packages. The free-induction decay (FID) corresponding to each voxel was filtered with a Gaussian, zero filled to 2048 points, Fourier transformed and corrected for frequency shifts, and then each peak in the spectrum was fitted with a Gaussian curve followed by a PCA [3]. Subsequently, Xe-129 CSI maps for each slice of each individual multiple-dissolved peaks and gas peak were calculated separately (Figure 2). The ratios among the different peak areas were determined and quantified (Figure 1).

Results:

Although the 2D-CSI projections produced higher in-plane resolution for each lung compartment, the 3D acquisitions provided superior regional information from the whole lung (Figs. 1 & 2). For example, focal elevations in the tissue/gas signal, most prominent anteriorly for the SHS subject, were contrary to the distribution observed in the healthy subject (Fig. 1) and consistent with previous observations [4, 5]. Both CF and SHS subjects showed an abnormally low signal from the RBC compartment.

Conclusions:

Multiple defects (no signal) could be observed for the CF subject in all three lung compartments (Fig. 2). This demonstrates that current map resolution is sufficient to detect focal disease. The Xe-129 3D-CSI technique is a promising tool for evaluating lung disease, and may offer more regional information than current clinical tools.

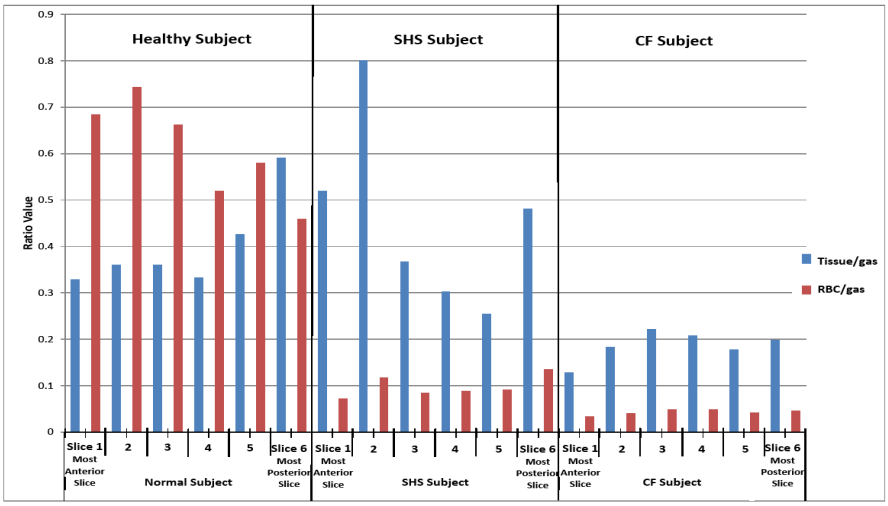

Figure 1: Regional information for tissue/gas and RBC/gas for subjects #5 (healthy), #6 (SHS) and #8 (cystic fibrosis).

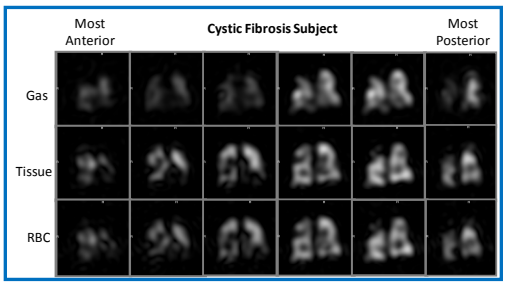

Figure 2: CSI maps of Xe-129 as gas in alveoli, and dissolved in tissue and or RBC, for subject #6 (SHS) and subject #8 (cystic fibrosis). For subject #8, note the defects present in all three lung compartments, demonstrating that current resolution is sufficient to evaluate focal and regional disease.

References: [1] Mata J et al. ISMRM, Stockholm, 2010 (abstract #989). [2] Mata J et al. ISMRM, Montreal, 2011 (abstract #2319). [3] Stoyanova R.et al. JMR 154, 2002. [4] Mugler et al. PNAS 107:21707-21712. [5] Driehuys et al. PNAS 103:18278-18283.

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