# 3D Regional Measurements of Alveolar Surface Area using 90° Single Breath XTC

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## Introduction

A chemical shift saturation recovery (CSSR) method [1] has been used to observe diffusion of hyperpolarized $^{129}$Xe from alveolar gas spaces to lung tissue and blood. In CSSR, the $^{129}$Xe magnetization in the tissue and blood, which are chemically shifted by ~200ppm from the gas phase resonance, are initially destroyed with a selective RF pulse. Subsequent recovery of the $^{129}$Xe magnetization in the septal tissue is then observed as a function of time *t*. We compute the fraction *F(t)*, which is the ratio of $^{129}$Xe magnetization in the tissue at time *t* relative to the $^{129}$Xe magnetization in the gas phase at *t*=0. By fitting *F(t)* to a 1D analytical model of diffusion with a blood flow term, estimates of (a) alveolar surface area per unit volume of gas ($S_A/V$), (b) septal thickness (*h*), and (c) blood transit time through the gas exchange region ($\tau$), can be obtained.[2,3] A single inhalation bolus of hyperpolarized $^{129}$Xe is sufficient to obtain *F*(t) vs. *t* data from the whole lung. Our aim, however, is to obtain regional measurements of [$S_A/V$, $h$, $\tau$ ]. For regional measurements of the septal uptake curve, the SNR is limited. Instead of obtaining the entire time dependence of the septal uptake curve with one breath-hold, we previously investigated the single breath Xenon Transfer Contrast (SB-XTC) method to acquire regional measurements of *F* at a single time point. Multiple inhalations are then required to acquire additional time points sufficient to obtain the time dependent septal uptake curve regionally. We recently realized, however, that XTC is a fundamentally different method than CSSR and does not produce identical results. XTC relies on the flux of $^{129}$Xe from both the gas phase to the tissue and vice-versa. CSSR only relies on diffusion of $^{129}$Xe from gas to tissue. One can show by induction, however, that if 90° pulses are used for XTC rather than traditional 180° pulses, the "depolarization per pulse" factor in XTC is identical to the *F(t)* factor obtained with CSSR. In this work, we report our first 3D regional measurements of $S_A/V$ using 90° SB-XTC.

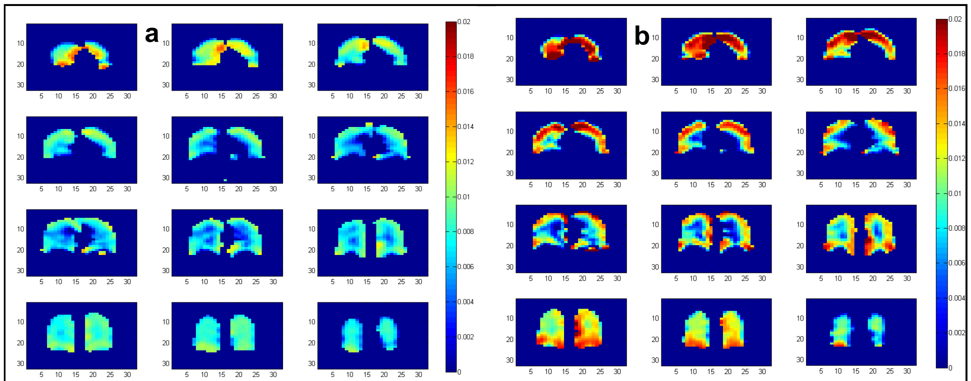


**Fig 1.** *F(t)* at (a) 44ms and (b) 62ms obtained from 2 separate acquisitions of 3D Single Breath 90° XTC. Color bar range for *F* = 0-0.02. Lung volume ~0.4 TLC.

## Methods and Results

Healthy subjects were studied with local IRB approval. A University of New Hampshire polarizer provided ~50% polarization @ 1L/hour. SB-XTC was implemented on a Siemens 3T Tim Trio. A 32 channel $^{129}$Xe RF coil was used [4]. The acquisition matrix was 16x16x8 and the data were zero filled by a factor of 2 in all dimensions. The spatial resolution was isotropic and equal to 2.2cm. The number of RF pulses used between image pairs was 90/40 with the total imaging time for each time point was 10/7 sec for experiments using 44/62 ms diffusion times, respectively. TE/TR was 2.3/5.1 ms. For an initial demonstration, we only acquired data at short times such that the septal uptake of $^{129}$Xe is diffusive and $F(t) \sim \sqrt{Dt}$, where D~3x10$^{-5}$ cm$^2$/s is the diffusivity of $^{129}$Xe in tissue [5]. The septal uptake curve for $^{129}$Xe is characterized by 3 regimes. At short times before the septa are saturated $F \sim \sqrt{t}$. After ~100ms, the uptake begins to level off as the septa approach saturation. At long times, there is a ~linear increase of *F* with time due to blood flow. Here we examined two diffusion times that are within the $\sqrt{t}$ regime: 44 and 62ms (see Fig. 1). Using an analytical form valid for the $\sqrt{t}$ regime[1], i.e. $F(t) = \lambda\, S_A / V \sqrt{4Dt/\pi}$ and a value for the Ostwald solubility (λ~0.1), the experimentally determined slope of $\Delta F / \Delta(\sqrt{t})$ was used to obtain regional values of $S_A/V$ (Figure 2).

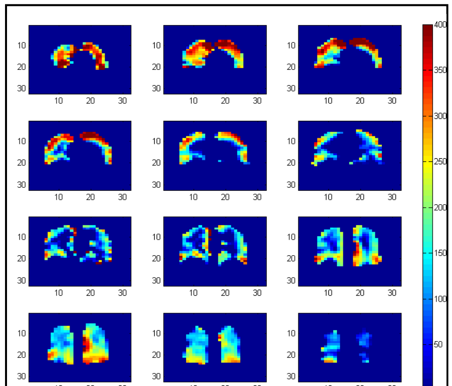

**Fig 2.** 3D $S_A/V$ map. The color scale ranges from 0-600cm$^{-1}$. The mean $S_A/V$ over the entire lung is 250cm$^{-1}$.

## Discussion

The mean $S_A/V$ = 250cm$^{-1}$ agrees with whole lung values obtained previously from normal healthy subjects at similar lung volumes [1]. A flip angle map was not acquired and therefore this may confound the data shown here. Regional noninvasive measurements of specific components of pulmonary physiology such as $S_A/V$ may be extremely important in early characterization and follow up of diseases such as COPD.

## Acknowledgements

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## References

1. Patz et al. *Acad Rad*, 15(6):713-727(2008).
2. Patz et al., *RSNA,* Chicago, November 2007.
3. Patz et al., *Proc ISMRM* #2678, Toronto, May 2008.
4. Dregely et al., *Proc ISMRM* #2203, Honolulu, May 2009.
5. Eger et al. *Brit. J. Anaesth.*, **36**:140-149(1964).