

Simultaneous Dissolved and Gaseous State ^{129}Xe Images at 0.2T

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Synopsis

Using a 2-point chemical shift method similar to the Dixon method¹, simultaneous ^{129}Xe projection images of both the gaseous state and that dissolved in corn oil have recently been obtained at 0.2T.

Introduction

Unlike ^3He , ^{129}Xe dissolves in tissue with a partition coefficient of ~ 0.1 . After breathing ^{129}Xe , it diffuses into the surface area of the parenchyma exposed to the gas. For short times, the dissolved state signal is proportional to the surface area of the lung. Thus dual images of the gas and dissolved state are useful as they give information about regional ventilation and surface area available for gas exchange respectively. Here we present initial results from a gas/corn oil phantom to demonstrate this method.

Methods and Results

Hyperpolarized ^{129}Xe gas was produced at the University of New Hampshire with initial polarization of $\sim 35\%$ (2). Polarized ^{129}Xe was collected by freezing it in a spiral-shaped, high surface area, glass cell. After ~ 1 bar-liter was accumulated, it was thawed into a 1 liter gas cell ($T_1 \approx 2$ hours) at pressures of ~ 1 atm. The gas was then transported by automobile in a portable holding field and delivered to the Brigham and Women's Hospital (BWH) ~ 2.5 hrs later.

The gradient power amplifiers of a clinical GE 0.2T Profile system (proton only) at BWH were modified to allow analog driver inputs so that a broadband research console (Tecmag Apollo, Houston, TX) could be used with this system. Home-made RF coils and a broadband RF power amplifier were added for operation at the ^{129}Xe frequency (2.36MHz). Projections were acquired at 2 chemical shift points corresponding to TE times: $t_A = 6.36\text{ms}$ and $t_B = 7.41\text{ms} = t_A + 0.5/\Delta\nu$, where the spectral shift between the gas and dissolved state corn oil signal was experimentally measured as $\Delta\nu = 472\text{Hz}$ (200ppm).

Reconstruction can proceed by the usual methods for the Dixon¹ technique. However, these methods still result in a chemical shift artifact that was seen both in experimental results and in simulations. As these artifacts are significant for ^{129}Xe , an alternative reconstruction is proposed based in part on chemical shift imaging experiments³. Ignoring relaxation effects, the sum and difference of the signals S acquired at the two different TE times is given by:

$$S_A \pm S_B = \int e^{i\gamma x t} \left[\rho_g(x) e^{i\omega_g t_A} (e^{i\omega_g t_A} \pm e^{i\omega_g t_B}) + \rho_d(x) e^{i\omega_d t} (e^{i\omega_d t_A} \pm e^{i\omega_d t_B}) \right] dx,$$

where "g" and "d" refer to the gas and dissolved-phase components respectively. We use an explicit first order phase factor to correct for the chemical shift displacements in the Fourier Transform. The gas and dissolved state projections are:

$$\int e^{i\gamma x t} \left[e^{-i\omega_d t} (S_A + S_B) \right] dt = \rho_g(x') e^{-i\omega_d t_o} 2 \cos(\omega_g \Delta t) + \rho_d(x' + \frac{\omega_g - \omega_d}{\gamma}) e^{i\omega_d t_o} 2 \cos(\omega_d \Delta t), \text{ and}$$

$$\int e^{i\gamma x t} \left[e^{-i\omega_d t} (S_A - S_B) \right] dt = \rho_d(x') e^{-i\omega_d t_o} 2i \sin(\omega_d \Delta t) + \rho_g(x' + \frac{\omega_d - \omega_g}{\gamma}) e^{i\omega_d t_o} 2i \sin(\omega_g \Delta t), \text{ where } t_A = t_o + \Delta t \text{ and } t_B = t_o - \Delta t.$$

The phantom used to test this technique consisted of two cells as shown in Figure 1. The reconstructed projection is shown in Figure 2. Notice there is still "bleeding" of one chemical shift species (particularly the large gas only signal) into the other (dissolved state projection). The reason for the bleed-thru is because the gas resonance frequency is not zero (in the rotating reference frame). To solve for this offset, one can acquire an additional data point, a method known as the 3 point Dixon technique⁴. In our case, however, to correct for this bleed-thru, we note that the signal in the vertically lower cell should contain only gas. Examining the form of the projections, we note that the ratio of the artifactual signal in the dissolved state (green signal in vertically lower cell) to the actual signal reconstructed for the lower cell (red signal in lower cell) equals $\tan(\omega_b \Delta t)$, from which one can determine the offset frequency ω_b , which in this case is 45Hz. To correct for this resonance offset, S_A and S_B are multiplied by $\exp(-i\omega_b t_A)$ and $\exp(-i\omega_b t_B)$ respectively before being used in the reconstruction equations and results in the projections shown in Fig. 3 where there is no observable "bleed-thru".

Discussion and Conclusions

The usual Dixon reconstruction performs the addition/subtraction after Fourier transformation. This may result in discernible chemical shift translation of gas phase pixels. The procedure outlined above, removes this artifact by a linear first order phase correction prior to Fourier transformation. The resonance offset can cause bleed-thru of signal from one chemical shift component into another. In this case, this was corrected by knowing that one cell contained only the gas phase.

References

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