V/Q Mapping using Inert Fluorinated Gas T1s

N. L. Adolphi[1], D. O. Kuethe[1]
[1]New Mexico Resonance, Albuquerque, NM, United States

Introduction: The T_1s of some inert fluorinated gases (e.g. SF_6, CF_4, C_2F_6) are dominated by the spin-rotation interaction, mediated by molecular collisions, and are very predictable. In lungs, the T_1s can be used to measure gas composition, because less massive molecules, such as O_2 and CO_2, are less effective mediators. One application is imaging the T_1 of C_2F_6 or SF_6 in lungs to map ventilation-to-perfusion ratios (V/Q), which are a monotonic function of the fluorinated gas T_1. The T_1 imaging method allows the subject to breath a 75% O_2 mixture during the entire procedure. This is an advantage over our prior method of mapping V/Q with spin density images of SF6 [1], requiring a reference image made while the subject breathes a normoxic gas mixture, which may be unpleasant for some pulmonary patients.

Methods: We developed a modified Look and Locker [2] T_1 sequence, which employs a series of low angle pulses, following an inversion pulse, to monitor the recovery. We simulated the pulse sequence numerically in order to adjust the pulse sequence parameters (number of pulses, tipangles, lengths of delays, etc.) to yield the lowest standard deviations of T_1 using the least experimental time. Compared to our original sequence parameters, the optimized parameters yield a 16-fold decrease in imaging time for comparable T_1 accuracy. The simulation demonstrates that because our sample (a gas) has inherently low S/N, the most effective "low angle" pulses are actually not very low (~ 45^o), and their depletion of longitudinal magnetization M must be entered into the calculation of the recovery curve. Further, the medium-angle inspection pulses are most effective in conjunction with delays between pulses comparable to T_1, longer than we had anticipated. The longer delays mean that there is enough time between pulses to collect good quality data from the faster-relaxing SF_6 (with T_1s in lung of ~0.9-1.6 ms). Imaging the T_1 of SF_6 reduces the experimental time by a factor of ~3 compared to imaging C_2F_6 (with T_1s in lung of ~4-7 ms). The T_1 sequence is combined with 3D FID projection imaging [3] to spatially resolve T_1. The T_1 sequence (inversion, followed by 8 medium-angle excitation pulses) is repeated for ~1400 different gradient directions, with an FID acquired after each excitation. A 3D spin density image is generated from each of the 8 excitation pulses in the T_1 sequence. T_1 is determined from the time-dependence of the spin density in each image voxel.

Results: We have obtained ^{19}F T_1 images of C_2F_6 and SF_6 mixtures in bundles of sealed test tubes and preliminary images of healthy rat lungs *in vivo* at 1.9 T. In our first 3D T_1 image of rat lung, the rat breathed an 80% C_2F_6-20% O_2 mixture in order to have the *same* T_1 (5.74 ms) for all lung pixels[1]. The isotropic resolution was 1.2 mm, and the imaging time was 80 minutes. Of the 5764 voxels in the lung (i.e. that gave a ^{19}F signal), 3644 voxels had a T_1 fitting error < 2 ms. For these 3644 voxels, the average T_1 was 5.98 ms with a standard deviation of 0.98 ms (16%) in good agreement with the expected value. Imaging the shorter T_1 of SF_6 in rats should result in improved T_1 accuracy for comparable imaging time.

References: [1] D.O. Kuethe et al, 'Imaging obstructed ventilation with NMR using inert fluorinated gases,' J. Appl. Physiol. 88:2279-86 (2000), [2] D.C. Look and D. R. Locker, 'Time saving in measurement of NMR and EPR relaxation times,' Rev. Sci. Instrum. 41:250-1 (1970). [3] D.O. Kuethe et al, 'Imaging lungs using inert fluorinated gases,' Magn. Reson. Med. 39: 85-8 (1998).