Effect of Echo Spacing on the T2 of Hyperpolarized He3 in the Healthy Human Lung at 1.5T

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Introduction: A previous study demonstrated that the T2 relaxation time for He3 in the human lung, as measured by a CPMG spin-echo-train with a 20-ms echo spacing, is much shorter at 1.5T than at 0.1T, and that the value at 1.5T depends strongly on the degree of lung inflation [1]. These results indicate that, for field strengths substantially above 0.1T, the observed signal decay is driven by diffusion of the He3 atoms through the local field gradients generated by susceptibility differences between lung tissue and air. It may therefore be expected that the T2 relaxation time at 1.5T would also vary as a function of the echo spacing in the CPMG train. In this work, the T2 for He3 in the human lung was measured in healthy volunteers at three different echo spacings.

Methods: He3 studies were performed in 5 healthy subjects using a 1.5-T whole-body scanner (Sonata, Siemens Medical Solutions) and a He3 flexible chest RF coil (Clinical MR Solutions). He3 gas was polarized by collisional spin exchange with an optically-pumped rubidium vapor using a prototype commercial system (Magnetic Imaging Technologies, Inc.). All experiments were performed under a Physician's IND for imaging with hyperpolarized He3 using a protocol approved by our institutional review board. Informed consent was obtained in all cases.

Spirometry was performed in each subject on the day of imaging. For the He3 acquisitions, each subject inhaled 900-950 ml of gas, containing 100 ml of He3 and the remainder nitrogen. A non-spatially-selective CPMG spin-echo-train pulse sequence was used to collect 32 echoes, with an echo spacing of 10, 20 or 30 ms, during a breath hold. The data for each echo spacing was collected during a separate breath-hold period. In two subjects, a second measurement was made with an echo spacing of 10 ms to obtain an indication of the reproducibility of the experimental conditions. The breathing maneuver used for these experiments is similar to condition "A" described in reference 1.

For each measurement, a non-linear least-squares fit of a mono-exponential decay was used to derive the estimate for the corresponding T2 relaxation time. Some data sets exhibited small signal oscillations over the first few points, and thus the first four data points of all measurements were excluded from analysis. The T2 estimates were made by analyzing approximately the same time period between the first and last echoes. Thus, for the 10, 20 and 30-ms data sets, 28 (270 ms between first and last echo), 15 (280 ms) and 10 (270 ms) echoes, respectively, were included in the analysis.

Results: The forced vital capacity (FVC) from spirometry and the T2 estimates for each echo spacing are listed in Table 1. The measured decay curves for subject 1072 are shown in Fig 1. The mean T2 values for the five subjects were 232, 182 and 160 ms for echo spacings of 10, 20 and 30 ms, respectively. For all five subjects, the T2 decreased as the echo spacing increased from 10 to 20 ms (mean decrease as a fraction of the T2 at 10 ms, 21% [$p<0.01$]), and for four of the five subjects the T2 decreased as the echo spacing increased from 20 to 30 ms (mean decrease as a fraction of the T2 at 20 ms, 11% [$p=0.11$]). For the two subjects in whom the 10-ms echo spacing measurement was repeated, the change in T2 between measurements was 3% or less. In four of the five subjects, there was a tendency for those with a larger FVC (and hence a lower inflation level, since the inhaled volume was nearly the same for all subjects) to have smaller T2 values, consistent with the observation of Vignaud et al that T2 values at 1.5T decreased as the degree of lung inflation decreased [1]. However, the remaining subject, with the smallest FVC, had, overall, the lowest T2 values.

The mean T2 value at an echo spacing of 20 ms (182 ms) is similar to that measured under condition "A" by Vignaud et al at 1.5T (139 ms) [1]. Our measurement is a bit higher, however, which is consistent with the fact that in our experiments the subjects inhaled 900-950 ml, whereas in the experiments of reference 1 the subjects inhaled approximately 500 ml for condition "A".

Conclusions: The T2 value for He3 in the healthy human lung was measured at 1.5T using a CPMG spin-echo-train pulse sequence with echo spacings of 10, 20 and 30 ms. There was a statistically significant decrease in the T2 value as the echo spacing increased from 10 to 20 ms, and a trend toward further decreases in T2 as the echo spacing increased from 20 to 30 ms. The dependence of T2 on echo spacing will be an important consideration for the optimization of echo-train pulse sequences for hyperpolarized-gas imaging.

References: **1.** Vignaud A et al. ISMRM 11 (2003); 1384.

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Table 1: Estimated T2 values [ms] as a function of echo spacing in five healthy subjects.

Subject #	FVC [L]	Echo Spacing			
		10 ms	20 ms	30 ms	10 ms (repeat)
1054	2.85	275	213	184	–
1057	4.45	199	165	171	–
1072	3.17	277	210	152	–
1074	3.77	206	165	152	199
1075	2.37	201	156	142	202

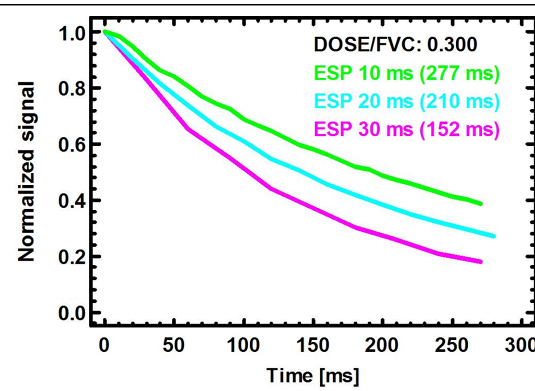

Fig. 1. Measured signal decays for subject 1072 for echo spacings of 10, 20 and 30 ms.