^3He T_1 in Mouse Lung estimated from Washout Curve Analysis under Spontaneous Respiration. Use of SF_6 Gas at Thermal Equilibrium to evaluate Respiratory Term

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Introduction: ^3He T_1 in the mouse lung was estimated under spontaneous respiration by the novel method, in which SF_6 gas at thermal equilibrium was utilized in combination with the hyperpolarized ^3He gas in the quantitative washout curve analysis. Here, ^{19}F in SF_6 gas has very short relaxation time of T_1 and T_2 with the order of a few msec, enabling to detect the signal after accumulation within a short time. Also, measurement under spontaneous respiration is noninvasive and readily applied to animals. Thus, the proposed novel method would be useful to diagnose the alveolar gas exchange function as well as the O_2 partial pressure in lungs of animals.

Washout model of HP ^3He gas and SF_6 gas: We applied ^{129}Xe washout model [1] to ^3He and SF_6 washout curve analysis. The signal intensities $S_{n\text{-}He}$ for ^3He and $S_{n\text{-}F}$ for ^{19}F in the nth excitation for the washout process under spontaneous respiration are given by

$$\ln(S_{n\text{-}He})=\{\ln(\cos\alpha)/TR-R_f/V_a-1/T_1\}(n-1)TR+\ln(S_1) \quad (1), \qquad \ln(S_{n\text{-}F})=(-R_f/V_a)(n-1)TR+\ln(S_1) \quad (2),$$

where α, R_f, V_a, and TR are flip angle, ventilation volume per second, total volume of alveoli, and repetition time, respectively. The slope of the ^3He washout curve as a logarithmic function is affected by three factors including RF pulse angle, respiration term, and longitudinal relaxation time. In contrast, the slope of the SF_6 washout curve is only the function of respiratory term because of the very short T_1 and T_2 values in SF_6 gas.

Materials and Methods: ^3He atoms were polarized by K-Rb hybrid spin-exchange optical pumping [2,3] with a homebuilt noble gas polarizer operated at atmospheric pressure and their polarizations were 6-8%. HP ^3He gas was applied to a male ddY mouse under anesthesia by spontaneous respiration through a mouth mask to which the oxygen gas was applied additionally. MRS measurements were performed on a Varian INOVA 400WB NMR spectrometer equipped with a 9.4T vertical magnet. ^3He spectra were obtained by repetitive RF pulse series in every 0.7s during washin, steady state, and washout processes. To obtain the washout spectra we switched the polarized gas to the depolarized gas. The flip angle α was determined by a dual flip angle method using 2α and α degree pulses [4]. ^{19}F spectra were obtained in every 0.12s and accumulated 6 times. ^{19}F washout curve was obtained by switching SF_6 gas to N_2 gas.

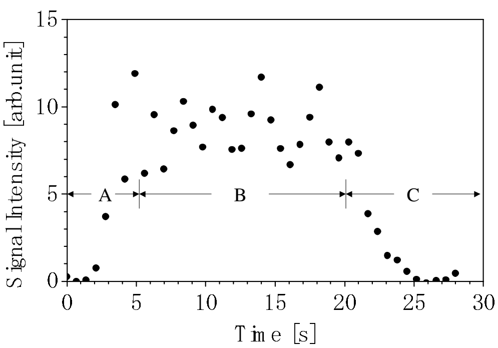

Fig.1: Signal dynamics of ^3He in the mouse lung during washin (A), steady state (B), and washout (C) processes.

Results and Discussion: As shown in Fig.1, the time evolution of ^3He signal intensity during washin (A), steady state (B), and washout (C) processes under spontaneous respiration was obtained successfully. In the steady state ^3He signal showed large oscillation which reflected the inhale-exhale cycle. Fig.2 shows the semi-logarithmic plots of ^3He signal intensities during washout process measured by the flip angle 2α and α degree pulses and their slopes were –0.491 and –0.367 respectively. The flip angle α~13° was determined from difference in these two slopes. The ventilation volume ratio $-R_F/V_A$~-0.315 was obtained from the slope of the SF_6 washout curve (Eq.2). By substituting these values into Eq.1, we could obtain the ^3He T_1 value of 86s. ^3He T_1 in the lung was dominated by O_2 partial pressure. At our condition, O_2 partial pressures calculated from ^3He and O_2 gas flow rates were 5-7kPa. The estimated T_1 value of 86s was moderate compared with the value calculated from literature data measured during breath-hold [5].

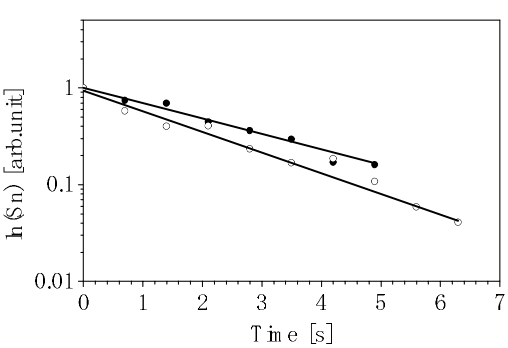

Fig.2: Semi-logarithmic plots of ^3He signal intensity during washout process measured by the flip angle of 2α (○) and α (●) degree pulses. Solid lines were obtained by the least-squares fitting.

Conclusion: ^3He T_1 in mouse lung was successfully estimated from washout curve analysis with the aid of SF_6 gas under spontaneous respiration. This novel method would be applied to animals noninvasively and readily, which would be useful for repeated animal study in long-term testing.

References

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