Pulmonary time constant of oxygen consumption evaluated by hyperpolarized ^{129}Xe MR

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Introduction Oxygen therapy is one of effective treatments for COPD (chronic obstructive pulmonary disease) patients, although the side effect of oxygen poisoning might occur, since it is hard to find a proper oxygen concentration. The usual method to evaluate the oxygen concentration clinically is to measure oxygen partial pressure in arterial through the blood gas analysis, which cannot directly offer the oxygen concentration in the lung. In recent years, hyperpolarized (HP) xenon MR offers a new tool to study the gas exchange function of the lung, due to its extremely high MR sensitivity, good solubility and chemical shift sensitivity. In this paper, we use hyperpolarized xenon to evaluate the lung by measuring the time constant of oxygen consumption.

Materials and Method To evaluate oxygen uptake in the lung, a time constant ($T_{O\text{-}C}$) of oxygen consumption is defined, which reflects the rate of lung absorbing oxygen. All the MR experiments were conducted on a Bruker Biospec 4.7T MRI scanner, together with a homebuilt polarizer with a spin polarization of ~15%. 16 SD rats weighted about 250g were used, including 8 healthy and 8 COPD rats. The MR pulse for measuring the time constant of oxygen consumption in the lung is shown in Figure 1, the first excited pulse with a flip angle of α1 (about 15 degree) was used to acquire a signal as a reference, which was used for the normalization by removing the effect of xenon relaxation in the Tedlar bag, and then a series of pulses (Gauss shape, 1ms) centered at 200ppm (relate to the gas phase) were applied to saturate the dissolved xenon signal. After that, the gas signal of the lung was acquired with an excited pulse (α2 = 90 degree). By changing the number of the saturation pulse, the dynamic xenon gas signal were acquired. To avoid the variations among different acquisitions, the time between two xenon signal acquisitions were fixed to be 3 s, which corresponded to the number of the loops ranged from 50 to 1000. To evaluate the effect of relaxation, the saturation pulse centered at -200ppm was used, and the results was shown in Figure 2, and the pulse sequence was applied in the healthy rats and the COPD rats.

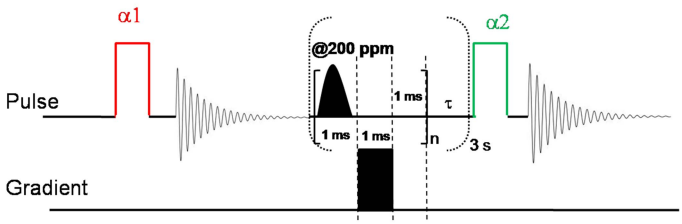

Figure 1, pulse sequence for measuring oxygen consuming time constant in lung

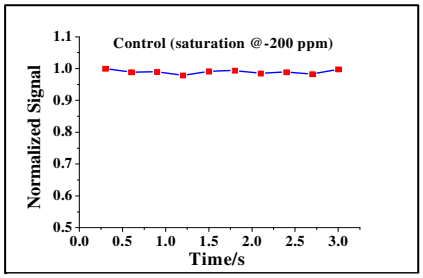

Figure 2, the control experiment, which the saturation pulse centered @ -200ppm

Results and discussion

The typical xenon gas signal with different saturation time were illustrated in Figure 3, and it obviously showed the difference between the healthy rat and the COPD one. When the data was fitted with the function $y=A*\exp(-t/T_{O\text{-}C})+A_0$, the time constant of oxygen consumption ($T_{O\text{-}C}$) can be obtained. In this study, eight COPD rats and eight healthy rats were measured (Table 1), exhibiting a significant difference between two groups. The time $T_{O\text{-}C}$ of COPD rats (0.88 s) is obviously larger (p=0.001) than that of healthy ones (0.60 s).

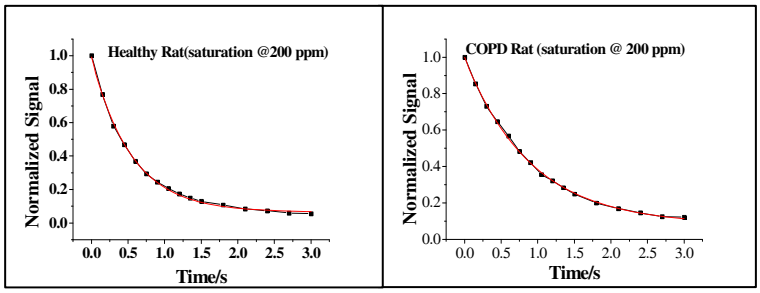

Figure3, the typical xenon gas signal varies with the saturation time in healthy rat(left) and COPD rat (right)

Table 1, the measured T in healthy rats and COPD rats

	Rat1	Rat 2	Rat 3	Rat 4	Rat 5	Rat 6	Rat 7	Rat 8	Mean	p-value
Healthy	0.66	0.56	0.68	0.54	0.56	0.6	0.49	0.69	**0.60±0.07**	**0.001**
COPD	1.23	0.88	0.81	0.71	0.86	0.84	0.78	0.93	**0.88±0.16**	

Conclusion We proposed a new method to evaluate the lung function by measuring the time constant of oxygen consumption ($T_{O\text{-}C}$) in the lung with hyperpolarized xenon MR. It demonstrated that such time constant has a significant difference between COPD and healthy rats, and we believe this parameter is helpful to quantify the oxygen concentration in oxygen therapy of patients.