Evaluation of Radiation-induced Lung Injury by Hyperpolarized Xenon

Zhiying Zhang[1], Haidong Li[1], Xianping Sun[1], Xiuchao Zhao[1], Chaohui Ye[1], and Xin Zhou[1]

[1]*National Center for Magnetic Resonance in Wuhan, Wuhan Institute of Physics and Mathematics, Chinese Academy of Sciences, Wuhan, Hubei, China*

Introduction Radiation therapy (RT) for thoracic-region tumors often causes radiation-induced lung injury (RILI), and it is over 1/3 RILI occurred in all thoracic radiation treatment cases. Although the RILI can be clinically monitored using the conventional pulmonary function measurements, the regional functional effects of the injury are not well understood. Hyperpolarized (HP) ^{129}Xe MRI is able to provide not only the structure but also the function information of the lung, because the pulmonary exchange function can be studied through the signal dynamics among xenon three chemical shifts in alveoli, TP (tissue and plasma) and RBC. In this work, we have experimentally demonstrated that HP xenon MRI has the capability to quantify microstructural change of the RILI with the model of MOXE (Model of Xenon Exchange) [1].

Material and Method HP xenon gas was produced by a homebuilt polarizer with a polarization about 15%, and HP xenon and oxygen were alternately ventilated to the rats through an anti-relaxation delivery system. The chemical shift saturation recovery (CSSR) sequence was used to acquire the MRS of healthy and RILI rats, and the exchange delay time varied from 2ms to 400ms after the second pulse during the xenon breathhold. All the experiments were conducted on a Bruker Biospec 4.7T MRI scanner with a homebuilt dual-tuned birdcage coil (^{1}H and ^{129}Xe).

Results and Discussion Followed by the application of an exponential filter function and Fourier transformation, the spectra were fitted to Lorentzian shape to extract the amplitude of TP and RBC xenon signal. Then, after the signal amplitudes normalized by the gas signal, the parameters of gas exchange function were fitted using the model of MOXE developed by Chang [1].

As shown in Figure 1, xenon signal from TP (197 ppm) and RBC xenon signal (212 ppm) has no much difference in the healthy rat, while the signal from TP increased in RILI rat. Figure 2 shows the dynamics of dissolved and gas-phase xenon signal in the lung as a function of the exchange time. Figure 3 shows xenon exchange time of the RILI rat are much longer than that of healthy rats. The parameters of alveolar microstructure, fitted using the model of MOXE, are shown in Table 1, demonstrating the significant different of xenon exchange time, pulmonary capillary transit time and total alveolar septal thickness between healthy and RILI rats ($p<0.005$). These changes characterized by hyperpolarized xenon MRI are identical with the HE-stained pulmonary sections pathologically.

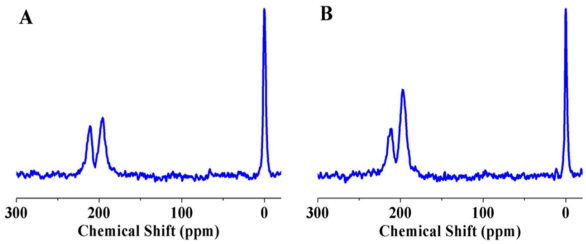

Figure 1. The typical dissolved xenon spectra in healthy rat (A) and RILI rat (B), and in RILI rat the xenon signal in blood is much smaller than that in tissue.

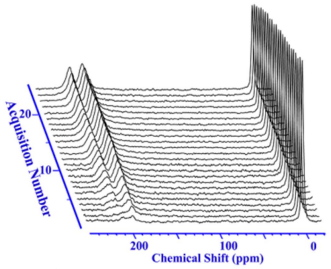

Figure 2. Dynamics of dissolved and gas-phase xenon signals in the lung as a function of the exchange time, varied from 2 ms to 400 ms.

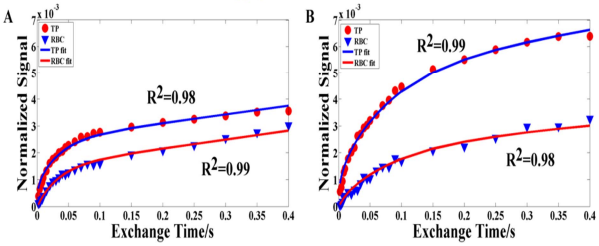

Figure 3. The dissolved xenon signals as a function of the exchange time (delay between the pulses in CSSR sequence) in the healthy (A) and RLIL rat(B).

Table 1. The parameters fitted using the model of MOXE

	Healthy	RILI
Xenon exchange time (ms)	44.5	112.0
Pulmonary capillary transit time (s)	0.5	1.5
Total alveolar septal thickness (μm)	12.0	19.1

Conclusion Our study shows that hyperpolarized ^{129}Xe MRI can noninvasively detect the RILI. By using the CSSR sequence and the model of xenon exchange to detect the exchange time in blood and tissue, ^{129}Xe MRI appears to be able to quantitatively evaluate and monitor the changes of lung functions, which is in agreement with the pathological results.

References: [1] Chang Y V, Magn Reson Med, 2012; 63:884-890.