Dynamic Oxygen-Enhanced MR Imaging: Effect of Breathing Rate

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Background and Purpose: Oxygen-Enhanced magnetic resonance imaging of the lung allows visualization of oxygen diffusion from the alveoli into the capillaries of the lung (1-3). This imaging technique can be used clinically for patients with emphysema and lung cancer (4). Previous studies were focused on the degree of signal enhancement by comparing the parenchyma signal before and after oxygen inhalation. However, signal enhancement is also influenced by airway flow limitation due to large or small airway disease. Few studies were performed to evaluate of dynamic signal changes after oxygen inhalation (5). The purpose of this study is to develop method for dynamic evaluation of oxygen-enhancement MR imaging and investigate the effect of breathing rate on oxygen enhancement.

Materials and Methods: Oxygen-enhanced MR imaging were performed with a respiratory synchronized inversion recovery single shot turbo spin echo sequence (TE 4 ms/ TI 900 ms/ echo spacing 4 ms/ slice thickness 10 mm/ NSA 1) using a 1.5T whole body scanner (Gyroscan Intera, Philips Medical Systems, Best, The Netherlands). Five healthy volunteers inhaled room air first, followed by 100% oxygen (15L/min) using non-rebreathing ventilation mask. The breathing rate was controlled by using the beep sound at 6 / min and 12 / min. Images of posterior lung were acquired at end-expiration in coronal plane. By using linear fitting algorithm, parametric maps of absolute signal difference, rate of signal enhancement (slope) and time to peak enhancement were generated (MATLAB, The Mathworks Inc., Natick, MA). Effect of breathing rate in these parameters was assessed by comparing the signal of region of interest in right upper lung.

Results: All experiments were performed successfully and the maps were successfully reconstructed from all subjects. Figure 1 shows examples plot of the time course of the signal intensity measured from region of interest in right upper lung and pixel-by-pixel maps of the absolute signal difference, rate of signal enhancement and time to peak enhancement. As shown in Table and Figure 2, the frequent breathing resulted in significant increase in the rate of signal enhancement. However, the absolute signal enhancement was not significantly influenced by breathing rate.

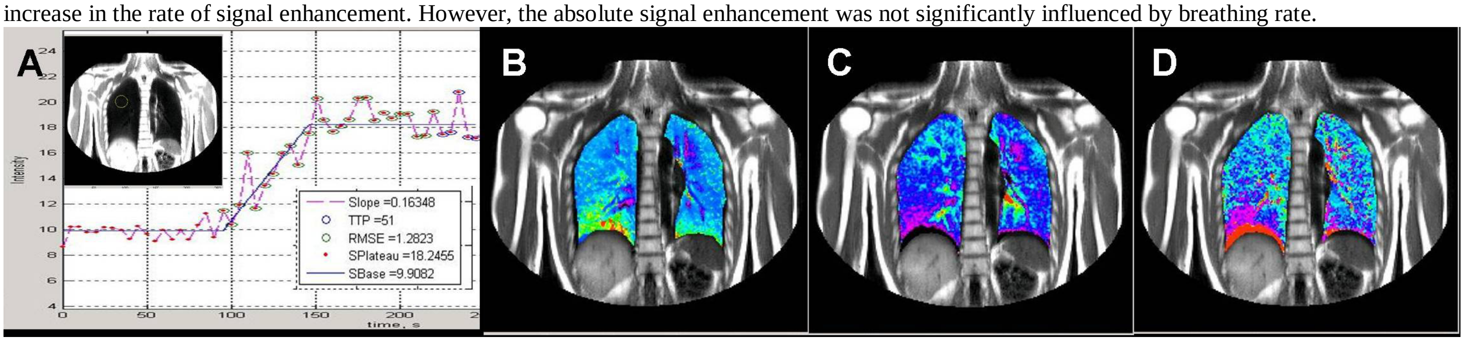

Figure 1. Oxygen-enhanced MR maps in a normal volunteer. (A) Time course of signal intensities of a normal, right upper lung with the resulting fitted line in linear function. (B) parametric map of the rate of signal enhancement (slope; signal intensity/sec) (C) map of absolute signal enhancement (D) map of time to peak.

	Breathing Rate		
	6/min (mean ± SD)	12/min	P-value
Slope (signal intensity/sec)	0.26 ± 0.15	0.41 ± 0.16	0.03
Absolute enhancement	11.39 ± 3.76	11.38 ± 3.31	0.5
Time to peak (sec)	56 ± 10	40 ± 12	0.03

Table. Comparison of dynamic enhancement factors according to the breathing rate in normal volunteers. Statistical test was done Wilcoxon signed rank test.

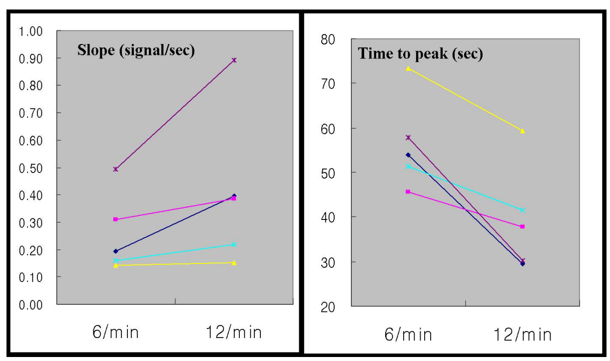

Figure 2. Graph showing the difference in slope and time to peak according to the breathing rate.

Discussion and Conclusion: This study shows that it is possible to assess dynamic component of oxygen-enhanced MR imaging with this proposed method. Effect of breathing rate on dynamic enhancement suggests the potential of this method in understanding pathophysiology of various pulmonary diseases in ventilation and diffusion function. Although further studies are needed, evaluation of slope of signal enhancement in addition to the absolute enhancement may provide comprehensive evaluation of pulmonary ventilation and diffusion including airway disease, airspace disease and interstitial disease.

References: 1. Edelman RR, et al. Nat Med 1996;2:1236–1239. 2. Muller CJ, et al. Radiology 2002;222:499–506. 3. Ohno Y, et al. Magn Reson Med.2002; 47: 1139-1144 4. Ohno Y, et al. AJR Am J Roentgenol. 2001; 177: 185-194. 5. May VM, et al. ISMRM Proc 2004;844