3He MR ventilation imaging under spontaneous breathing condition in a rodent model of broncho-constriction induced by serotonin

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INTRODUCTION

Hyperpolarized He-3 MRI of the lung is a technique with a high spatial and temporal resolution that allows visualization of gas dynamic during the respiration. In this study, we report a 3He MR ventilation imaging study on spontaneous breathing rats following broncho-constriction induced by serotonin. Lung function maps assessing airflow obstruction – a key feature in clinical pneumology- were derived from dynamic image series.

METHODS

Six Sprague-Dawley rats were anesthetised by intraperitoneal injection of a ketamine, xylazine and atropine mixture. A catheter was placed in the vein tail for serotonin injection. Following anaesthesia, a home built mask was fixed on the animal's head. The animal was placed supine in the RF coil. A 40mL 3He reservoir was connected to the mask and the ventilation images were acquired during spontaneous breathing of the animal. 3He MR acquisitions were performed using a radial k-space scanning sequence (200 radial projections per image, no slice selection, coronal plan, TR/TE= 5ms / 40µs, 12° flip angle, FOV=8 cm, 128*128 pixels). In total, 20 k-space sweeps were performed corresponding to a total acquisition time of 20s. 100 ms-resolved dynamic ventilation MR images were obtained from a retrospective cine image reconstruction procedure. The time shift between two consecutive images was 5 ms by using the sliding window approach. For each rat, ventilation acquisitions were performed before and 10 second after intravenous injection of 50µg/kg of serotonin. Two parameters defined as *signal amplitude* (SA) and *maximum signal decay rate* (MSDR) during gas expiration were extracted from time course of the NMR signal for each pixel (figure 1) and parametric maps were derived (figure 2). For each acquisition, the mean values of SA and MSDR were calculated over a manually selected ROI (150-200 pixels) placed in the lower part of the right lung where the higher signal was observed (table 1).

RESULTS

Maximum signal amplitude (SA) maps and maximum signal decay rate (MSDR) maps were obtained for each of the six rats. A global decrease of these parameters was found after serotonin injection (figure 2). Quantitative analysis obtained over the ROIs showed an average decrease of mean SA of 40 % in the lower part of the right lung after serotonin injection associated with an average decrease of mean MSDR of 36 %. A paired student's test showed that these variations were statistically significant for SA ($p<0.006$) and MSDR ($p<0.02$).

DISCUSSION AND CONCLUSIONS

After intravenous delivery, serotonin leads to bronchial tree smooth muscles constriction resulting in reduced expiratory gas flow values and to a decrease of the tidal volume. In clinical practice, ventilation obstructive disorders are characterised by decrease of expiratory flow during forced expiratory maneuver. Assuming that 3He signal intensity values are related to gas volume, the SA and MSDR parameters represent respectively the tidal volume and the expiratory gas rate and the findings of this study reflect the expected effects of the serotonin injection (decrease of the expiratory flow leading to a decrease of the tidal volume).

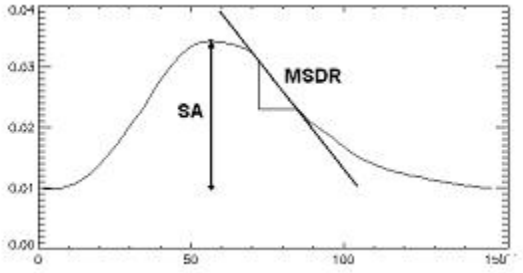

Figure 1. typical time course (ms units) of NMR signal in a pixel (arbitrary units). For each pixel, the parameters signal intensity (SA) and maximum signal decay rate (MSDR) are extracted from the curve.

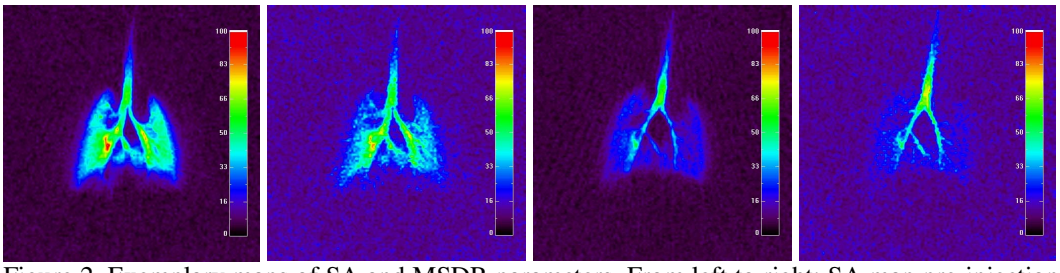

Figure 2. Exemplary maps of SA and MSDR parameters. From left to right: SA map pre-injection, MSDR map pre-injection, SA map post-injection, MSDR map post-injection. SA and MSDR color tables are expressed in arbitrary units.

	Rat 1		Rat 2		Rat 3		Rat 4		Rat 5		Rat 6	
	control	serotonin	Control	serotonin	control	serotonin	Control	Serotonin	control	Serotonin	control	serotonin
SA	5.9 ± 0.6	4.0 ± 0.6	7.8 ± 1.0	6.9 ± 0.8	8.1 ± 1.1	4.0 ± 0.6	11.4 ±2.2	6.9 ± 1.0	6.7 ± 1.6	3.2 ± 0.9	11.3 ±1.1	5.3 ± 0.6
MSDR	2.3 ± 0.5	2.3 ± 0.5	2.8 ± 0.7	2.5 ± 0.3	3.9 ± 1.0	1.9 ± 0.4	4.2 ± 0.9	2.5 ± 0.4	2.9 ± 0.7	1.6 ± 0.4	3.6 ± 0.5	1.8 ± 0.3

Table 1. Mean values of SA and MSDR in the lower part of the right lung expressed in arbitrary units (+/- standard deviation)