Dynamic oxygen-enhanced MRI in patients with pulmonary arterial hypertension

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Introduction: Oxygen-enhanced MRI (O_2-MRI) of the lung is based on the T_1-shortening effect of oxygen (O_2) inhalation and provides combined information about pulmonary ventilation, perfusion, and diffusion [1–9]. Dynamic O_2-MRI acquires (in each pixel) the signal time course influenced by the alternating administration of room air and O_2. By fitting a model function (pixelwise) to the acquired data, several parameters such as the relative signal increase, the signal delay as well as the O_2 wash-in and wash-out time constants can be obtained [2,4,6,8,9].

The purpose of this study was to determine the value of dynamic O_2-MRI in patients with pulmonary arterial hypertension (PAH) by comparing the distributions of the fitted parameters with those found in healthy volunteers.

Methods: We studied 11 healthy volunteers and 20 patients with PAH using a T_1-weighting multi-slice inversion-recovery half-Fourier-acquisition single-shot turbo-spin-echo (HASTE) sequence (TI=1300 ms, TE=11 ms, 4 slices, slice thickness 8 mm, slice distance 16 mm, matrix 128×128, FOV 400×400 mm², GRAPPA acceleration factor 2) implemented on a 1.5-Tesla whole-body scanner (Magnetom Sonata, Siemens Healthcare, Erlangen, Germany) with an 8-channel phased-array thorax coil system. Each examination consisted of a series of 60 acquisitions (20×air, 20×O_2, 20×air) with ECG and respiratory triggering for acquisition in end-expiration. Lung tissue was segmented manually in all 31 subjects (124 slices); the diaphragm position was used to discard automatically acquisitions with deviating levels of expiration. We normalized all data pixelwise to their mean value over the 20 initial baseline (air) acquisitions to obtain relative enhancement data for further analysis.

All data were pixelwise fitted with a piecewise exponential function depending on 4 parameters: the relative signal increase, R_{enh}; the delay, Δt, between switching the gas supply and onset of the signal changes; the (exponential) O_2 wash-in time constant, τ_{in}, and the O_2 wash-out time constant, τ_{out} [9]. For each subject, the distribution of these parameters was analyzed by determining the individual median value and the range (i.e. the difference between the 16th and 84th percentile) over all pixels (including all 4 acquired slices). Median values and ranges were compared between volunteers and PAH patients using the Wilcoxon two-sample test.

Results: The results of the parameter fitting and the statistical comparison are summarized in Table 1. The median values of all 4 estimated parameters were similar (i.e. not significantly differing) in patients and volunteers. However, the parameter ranges observed within the lung tissue of each single subject differed significantly for the relative enhancement, the delay, and the O_2 wash-out time constant. In all cases, the range was larger in the patients than in the volunteers. Examples of the parameter maps of all 4 parameters in a volunteer and a patient are shown in Fig. 1; these maps demonstrate the larger parameter variability in the PAH patient.

Table 1: Comparison of parameters in volunteers and patients: mean values (standard dev.)

	R_{enh} (%)	Δt (s)	τ_{in} (s)	τ_{out} (s)
Volunteers; parameter median (n=11)	17.5 (6.6)	5.8 (6.2)	31.7 (17.1)	28.2 (12.6)
Patients; parameter median (n=20)	14.4 (7.5)	4.2 (4.7)	30.7 (21.2)	46.0 (32.3)
p-value (volunteers vs. patients)	0.167	0.522	0.397	0.312
Volunteers; parameter range (n=11)	14.3 (4.2)	14.3 (4.8)	63.8 (30.1	63.4 (49.8)
Patients; parameter range (n=20)	19.7 (7.9)	24.5 (16.1)	73.2 (47.3)	121.1 (51.9)
p-value (volunteers vs. patients)	**0.018**	**0.024**	0.853	**0.005**

Conclusions: Our results indicate that dynamic O_2-MRI is feasible to detect pathological changes of the lung in patients with PAH. Interestingly, the median values over the complete lung tissue were similar in patients and volunteers, but the parameter ranges were found to be systematically increased in patients. This might be explained by the fact that most patients suffered from local/regional pulmonary defects due to the PAH, which cause a larger regional variation within the parameter maps. The most obvious difference between patients and volunteers was the increased range of the O_2 wash-out time constant in patients (121 s) compared to the volunteers (63 s).

References: **[1]** Edelman RR et al. Nat Med 1996;2: 1236–9 **[2]** Hatabu H et al. Eur J Radiol 2001;37:172-8 **[3]** Mai VM et al. Magn Reson Med 2003;49:591–4 **[4]** Arnold JF et al. MAGMA 2004;16:246–53 **[5]** Dietrich O et al. Magn Reson Med 2005; 53: 1317–25 **[6]** Naish JH et al. Magn Reson Med. 2005; 54: 464–9 **[7]** Molinari F et al. Invest Radiol 2006;41:476–85 **[8]** Ohno Y et al. AJR Am J Roentgenol 2008;190:W93-9 **[9]** Dietrich O et al. Proc. ISMRM 2009;17:2018

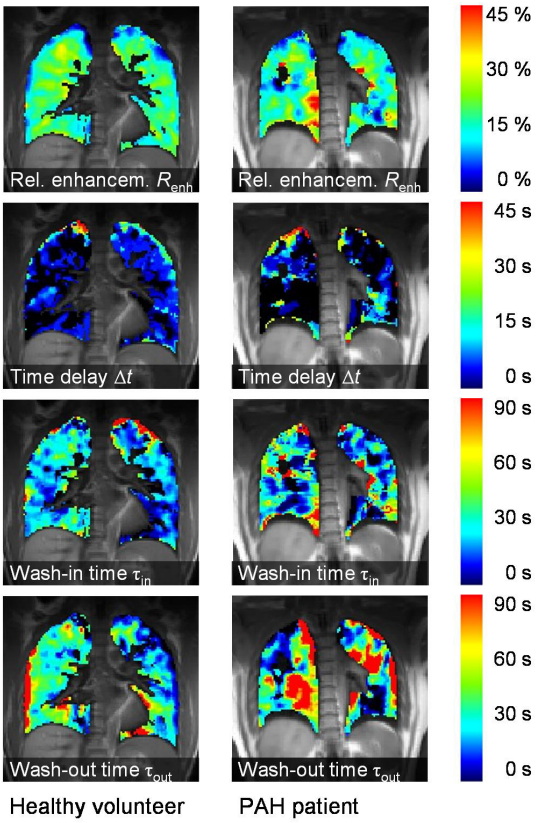

Fig. 1: Parameter maps of a single slice (out of four acquired slices) in a healthy volunteer (left) and a PAH patient (right). Note the increased regional variability of the parameters in the patient.