Regional assessment of pulmonary function using rapid dynamic acquisition of T1-maps

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Introduction: Recently, several investigators have reported that dynamic oxygen-enhanced MRI reflects lung function [1,2]. Using T_1-weighted sequences, relative enhancement ratios and mean slopes of relative enhancement have been measured. However, care should be taken while adopting the T_1-weighted approach, since the relative signal intensity of a T_1-weighted experiment is not a linear function of T_1. The slope of signal enhancement is not constant throughout the whole range of T_1 values seen in the lung, and therefore care should be taken while using mean slopes of relative enhancement and relative enhancement ratios when making quantitative comparisons of the pulmonary function of lungs. As an alternative, we report a technique to dynamically image lung function with oxygen-enhanced MRI using T_1-parameter-maps. This provides an accurate, quantitative assessment of T_1-relaxation-rate-enhancement (R_1-enhancement) versus time during inhalation of molecular oxygen, which is unbiased by the intrinsic T_1 of the lung. The possibility of fast and dynamic T_1-mapping, without waiting for full relaxation between the acquisition of subsequent maps, has already been reported [3]. To achieve an even higher temporal resolution, we developed a technique [4] which has an improved signal to noise ratio per unit time in comparison with the previously reported approach.

Subjects and Methods: All experiments were performed using a clinical 1.5 T whole-body scanner (Vision, Siemens, Erlangen, Germany) with a peak gradient amplitude of 25 mT/m and slew rates of 83 T/m/s. For signal reception a four-element body phased array coil was used. Measurements on a phantom were performed, to confirm that our dynamic T_1-mapping procedure provides accurate T_1 measurements. Lung T_1-maps of eight healthy volunteers were then dynamically acquired using a technique based on IR Snapshot FLASH [5]. Imaging parameters for Snapshot FLASH imaging for phantom and in vivo were TE = 1.4 ms, TR = 3.5 ms, FA = 7°, FOV = 500 mm^2, slice thickness = 15 mm and an image matrix of 64 x 128 zero-filled to 256 x 256. The total acquisition time for a single image was 224 ms. In a dynamic series, consecutive T_1-maps were acquired every 6.7 seconds. For comparison with the MRI measurements, the volunteers also underwent routine pulmonary function testing on a body plethysmograph (Masterlab, Jaeger, Wuerzburg, Germany).

Results: Table 1 shows an excellent agreement of the dynamically acquired T_1 values and the reference T_1 values on a phantom. The largest deviation from a reference value was 0.3 %.

Ref. T_1 / ms	735.2 ± 0.7	800.4 ± 1.3	850.9 ± 0.7	882.2 ± 0.6	982.7 ± 0.5	1056.2 ± 1.6	1164.5 ± 1.3	1304.3 ± 3.5
Dynamic T_1 / ms	735.2 ± 1.0	800.5 ± 0.8	851.4 ± 1.0	882.1 ± 0.9	981.7 ± 1.5	1057.0 ± 1.2	1168.0 ± 1.7	1304.0 ± 3.1

Table 1. *Measurement of T_1 in a phantom. Comparison between standard (ref.) and dynamic acquisition.*

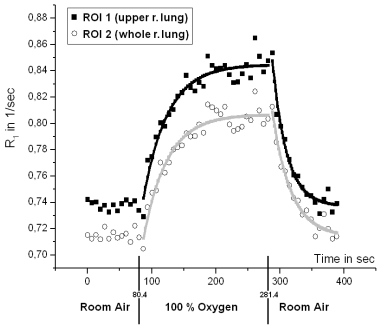

Figure 1. *Time course curves of R_1-enhancement from the upper and whole right lung of a volunteer.*

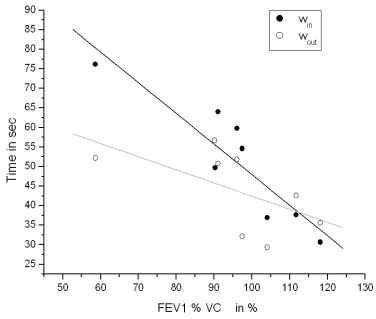

Figure 2. *Correlation of wash-in (w_{in}) and wash-out (w_{out}) time constants of the whole right lung of 8 healthy volunteers with their forced expired volume in one second in percentage of the vital capacity (FEV1%VC, percentage predicted). Black line: w_{in}; R^2=0.82; P=0.00199. Gray line: w_{out}; R^2=0.33; P=0.13555*

Figure 1 shows time course curves of R_1-enhancement of two ROIs (upper and whole right lung). The time course curves were fitted by exponential curves, in each case after switching of the breathing gas. The time constants of the exponential curves are the wash-in time constant w_{in} and the wash-out time constant w_{out}. The overall average of w_{in} (w_{out}) of all eight volunteers is 47.21 s (45.79 s) in the upper right and 51.20 s (43.90 s) in the whole right lung. Figure 2 shows a strong correlation of w_{in} with FEV1%VC and a suboptimal correlation of w_{out} with FEV1%VC.

Discussion: The results of the measurements on the phantom clearly demonstrate the feasibility of rapid dynamic T_1-mapping. Using rapid dynamic acquisition of T_1-maps during oxygen enhancement, time course curves of R_1-enhancement can be obtained. With the R_1-enhancement time constants of wash-in and wash-out, two new parameters for regional evaluation of pulmonary function are available. The wash-in time constant averaged over the whole right lung shows a strong correlation to the pulmonary function test parameter FEV1%VC and, therefore, could depict regional ventilation information. The proposed method may therefore have a potential to provide quantitative information on the time scale of oxygen transfer in various lung diseases.

References:

1) Mueller CJ, et al [2002] Radiology Feb 222(2): 499-506.
2) Ohno Y, et al [2001] AJR 177:185-194.
3) Deichmann R, et al [1999] MRM 42 :206-209
4) Arnold JFT, et al [2003] MAGMA, submitted
5) Jakob PM, et al [2001] JMRI 14 :795-799