Oxygen-enhanced MRI of the lung: Optimized calculation of difference images

O. Dietrich[1], M. Peller[1], U. Fasol[1], C. Losert[1,2], K. Nikolaou[1], M. F. Reiser[1], S. O. Schoenberg[1]

[1]Department of Clinical Radiology - Grosshadern, Ludwig Maximilian University of Munich, Munich, Germany, [2]Department of Radiotherapy and Radiation Oncology, Ludwig Maximilian University of Munich, Munich, Germany

Introduction: Oxygen-enhanced MRI (O_2-MRI) of the lung allows spatially resolved visualization of oxygen diffusion from the alveoli into the capillaries of the lung [1–5]. A commonly used method to assess lung function by O_2-MRI is to calculate the relative signal difference of acquisitions during inhalation of pure oxygen and room air [1–4]. After switching the gas supply, a relatively slow signal change with time constants between 30 s and 70 s is observed (cf. Fig. 1) [5]. Since these time constants can also be used to assess the lung function [4], a continuous data acquisition is desirable. The purpose of this study was to analyze how difference maps of continuously acquired data are influenced by this slow signal change.

Subjects and Methods: 10 healthy volunteers were examined with an ECG- and respiratory-triggered T_1-weighting inversion recovery HASTE sequence (TI = 1300 ms, TE = 11 ms, TR: 1 respiratory cycle, slice thickness 8 mm, slice distance 16 mm) implemented on a 1.5 T whole-body scanner (Magnetom Sonata, Siemens Medical Solutions, Germany). Parallel imaging (acceleration factor: 2) with the GRAPPA algorithm was used to reduce the TE and to increase the maximum number of slices acquired per respiratory cycle. 4 blocks with 20 repetitions of 4 or 6 coronal slices were continuously acquired; in blocks 1 and 3 room air was supplied, in blocks 2 and 4 oxygen. Data was post-processed discarding between n=0 and n=19 repetitions after each change of gas supply before calculating the relative signal difference $\Delta S_{\text{rel}} = \left(S_{\text{O2}} - S_{\text{air}}\right)/S_{\text{air}}$; see Fig. 1. To asses the data quality of the resulting difference map, the ("spatial") standard deviation of the pixel-wise calculated signal difference within the lung tissue was determined.

Results: As shown in Fig. 2a, the averaged relative signal difference is increasing from 9.4 % to 17.4 % and the spatial standard deviation of the signal difference is increasing from 6 % to 14 % when the number of discarded acquisitions is increased. The ratio of signal difference and spatial standard deviation has a maximum at 5 to 8 discarded acquisitions (Fig. 2b). Examples of difference maps demonstrating increasing statistical noise with increasing number of discarded measurements are shown in Fig. 3.

Conclusions: An optimized ratio of signal difference and statistical error is found if about 5 to 8 of 20 repetitions (corresponding to 5 to 8 respiratory cycles, i.e. about 60 seconds) are discarded after each change of gas supply for the calculation of difference maps.

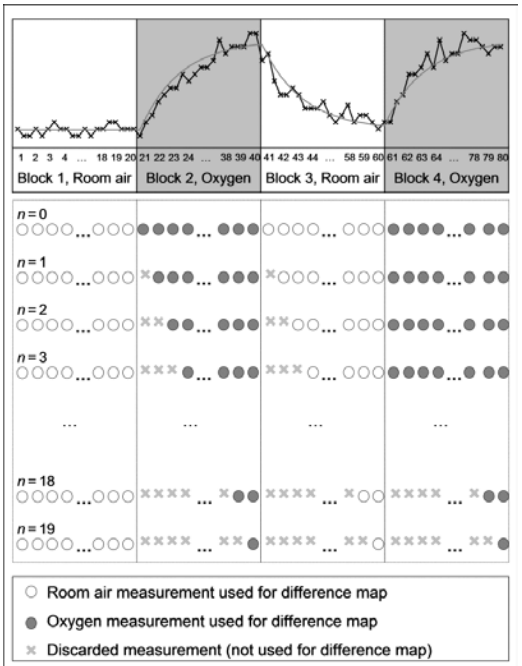

Figure 1: Physiological signal timecourse in O2-MRI of the lung (top) and selection of measurements used to calculate the difference maps (*n*: number of discarded measurements after change of gas supply).

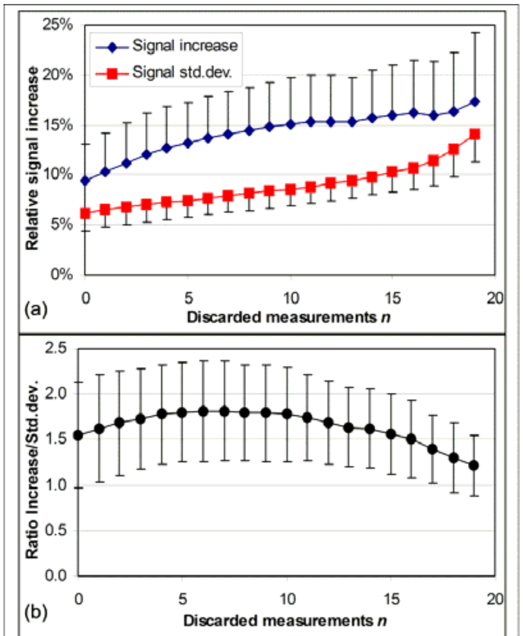

Figure 2: (a) Dependence of the signal increase and spatial standard deviation in the lung on the number *n* of discarded measurements. (b) Ratio of signal increase and spatial standard deviation as a measure of signal quality.

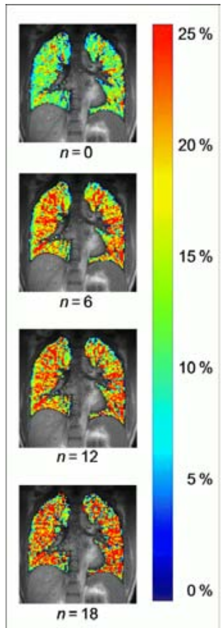

Figure 3: Examples of difference maps showing the relative signal increase for *n*=0, 6, 12, and 18 discarded measurements.

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