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

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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 (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 calculated from continuously acquired data are influenced by this slow signal change.

Subjects&Methods: 10 healthy volunteers were examined with an ECG- and respiratory-triggered T1-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 $\Delta S_{\mathrm{rel}} = (S_{O_2} - S_{\mathrm{air}})/S_{\mathrm{air}}$; 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: Examples of difference maps with increasing numbers, n, of discarded measurements are are shown in Fig. 2. A quantitative analysis of results is presented in Fig. 3: 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, n, of discarded acquisitions is increased (Fig. 3a). The ratio of signal difference and spatial standard deviation has a maximum at 5 to 8 discarded acquisitions (Fig. 3b).

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.

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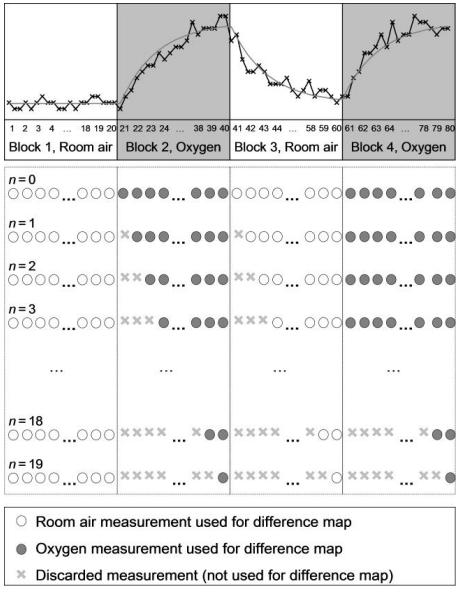

Figure 1: Physiological signal timecourse in O_2-MRI of the lung (top) and selection of measurements used to calculate the difference maps (n: number of discarded measurements after change of gas supply).

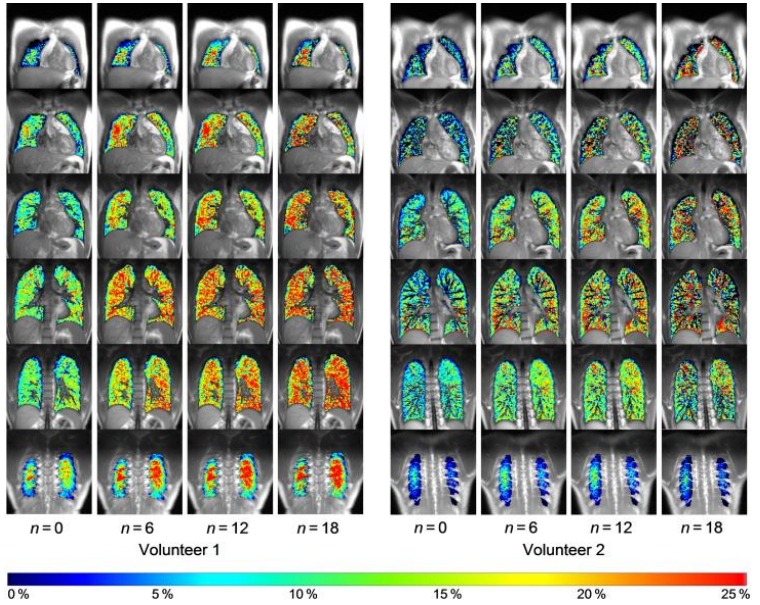

Figure 2: Examples of difference maps showing the relative signal increase for $n = 0, 6, 12$, and 18 discarded measurements (data from volunteer examinations with interleaved acquisition of six coronal slices). With increasing number of discarded measurements, n, the average signal difference as well as the spatial standard deviation (image noise) increase.

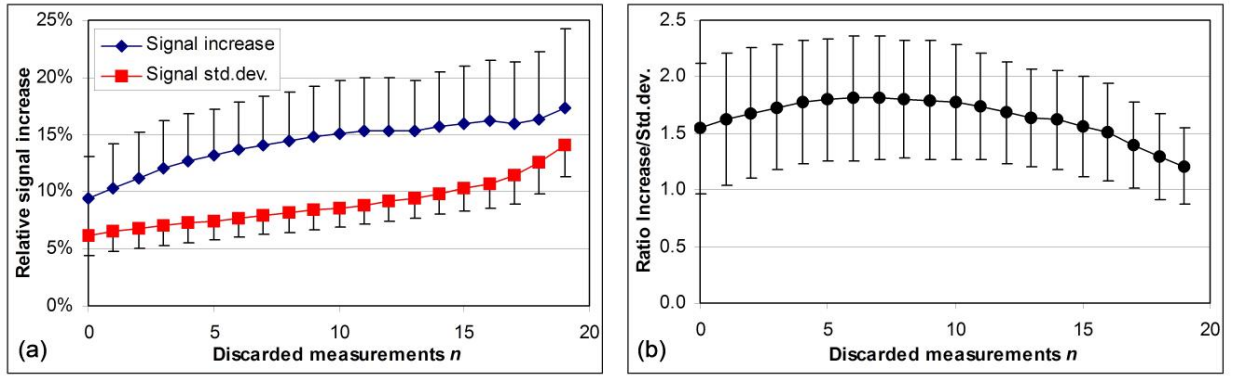

Figure 3: (a) Dependence of the signal increase and spatial standard deviation in the lung on the number n of discarded measurements. (b) Ratio of signal increase and spatial standard deviation as a measure of signal quality.