Oxygen-enhanced MRI of the Lungs: Intraindividual Comparison between 1.5 and 3 Tesla

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Introduction: Oxygen-enhanced MRI (O_2-MRI) of the lungs is based on the inhalation of pure oxygen (O_2), which reduces the longitudinal relaxation time, T_1, of pulmonary blood. This effect can be detected by comparing T_1-weighted MR signal intensities in acquisitions with inhalation of room air and oxygen [1–9]. Most studies of O_2-MRI are performed at a magnetic field strength of 1.5 Tesla; alternatively, low-field systems with e.g. 0.2 Tesla have been used since the signal-to-noise ratio (SNR) of lung tissue benefits from lower fields due to the high level of pulmonary susceptibility variations [2,3]. Recently, 3-Tesla MR systems have become clinically widely available. Theoretically, 3-T MRI offers an approximately doubled SNR compared to 1.5 T; however, susceptibility effects are considerably increased at 3 T and must be expected to reduce the SNR in the lung tissue. Up to now, the quantitative effect of high magnetic fields on signal changes caused by oxygen breathing has not yet been examined.

The aim of this study was to assess the feasibility of O_2-MRI at 3 Tesla and to compare the signal characteristics intraindividually with those at 1.5 Tesla.

Methods: 13 healthy volunteers underwent O_2- MRI at 1.5 and 3 Tesla. A single-slice non-selective inversion-recovery half-Fourier-acquisition single-shot turbo-spin-echo (HASTE) sequence with simultaneous (navigator-based) respiratory and cardiac triggering was applied in coronal orientation. Sequence parameters were TI=1300 ms, TR=1 respiratory cycle, TE=16 ms, FOV=500×500 mm², matrix size=128×128; slice thickness=20 mm. 40 measurements were acquired during inhalation of room air and, after switching the gas supply and waiting for 3 minutes, 40 more measurements were acquired during inhalation of oxygen.

The SNR of lung tissue was determined with a difference image technique. Further image post-processing included a retrospective motion-correction by discarding acquisitions with inconsistent diaphragm position and spatial filtering (smoothing with a Gaussian filter). The mean value of the relative signal enhancement in the lung parenchyma and its regional coefficient of variation, i. e., the regional standard deviation of the relative signal enhancement over the segmented lung divided by its mean value, were then calculated as measure of the oxygen-induced signal enhancement.

Results: The mean SNR at 1.5 T was 68.7 (standard deviation 18.6) in acquisitions with inhalation of room air and increased to 71.0 (21.6) with O_2. The mean SNR at 3 T was 76.5 (31.1) with room air and increased to 82.6 (32.1) with O_2.

The mean relative signal enhancement of the lung parenchyma due to oxygen breathing was 13% (5.6%) at 1.5 T and 9.0% (8.0%) at 3 T. The regional coefficient of variation of the observed O_2-indcued signal was 58.8% (38.1%) at 1.5 T and 155.0% (122.1%) at 3 T, which was significantly higher ($p < 0.05$, Wilcoxon matched-pairs signed ranked test) than at 1.5 T.

Visual assessment of the enhancement maps (cf. Fig. 1) showed a considerably less homogeneous distribution of the signal enhancement at 3 T.

Conclusions: Oxygen-enhanced pulmonary MRI is feasible at 3 Tesla. However, currently, the signal enhancement is significantly more heterogeneous and slightly lower at 3 T than at 1.5 T. Most likely, the predominant factor responsible for this inferior performance at 3 T is the lower B_1 homogeneity: The well-known B_1 (or flip angle) inhomogeneity at 3 T [10] results in a partially imperfect inversion and, thus, in very different T1-weighting in different areas of the lungs. Therefore, further optimizations such as improved B_1 uniformity and more robust inversion pulses are required to finally allow an effective integration of oxygen-enhanced MRI in comprehensive pulmonary MRI protocols at 3 Tesla.

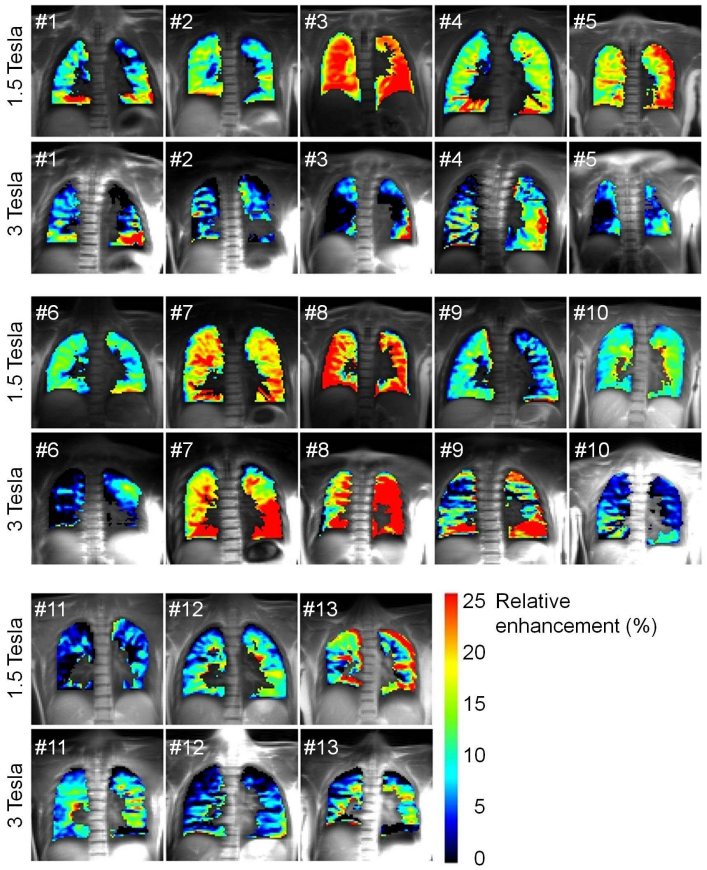

Fig. 1: Signal enhancement maps of all 13 volunteers (top row: 1.5 T; bottom row: 3 T). Note the increased heterogeneity of the 3-Tesla acquisitions.

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