

Fast oxygen-enhanced multi-slice MR imaging of the human lung using integrated parallel acquisition techniques (iPAT)

O. Dietrich¹, C. Losert^{1,2}, U. Fasol¹, U. Attenberger¹, K. Nikolaou¹, S. O. Schoenberg¹, M. Peller¹, M. F. Reiser¹

¹Department of Clinical Radiology, Ludwig Maximilians University of Munich, Munich, Germany, ²Department of Radiotherapy and Radiation Oncology, Ludwig Maximilians University of Munich, Munich, Germany

Introduction:

Oxygen-enhanced magnetic resonance imaging of the lung allows spatially resolved visualization of oxygen diffusion from the alveoli into the capillaries of the lung [1, 2]. For many pulmonary diseases, this method appears to be an ideal supplement to perfusion imaging of the lung [3]. Hence, short examination durations are desirable in order to integrate oxygen-enhanced MRI of the lung, perfusion imaging, and other techniques like pulmonary MR angiography into one examination protocol. Integrated parallel acquisition techniques (iPAT) allow for shorter acquisition times and can improve image quality in single-shot imaging sequences. The purpose of the present study was to evaluate iPAT methods for oxygen-enhanced lung imaging in combination with an optimized respiratory and cardiac triggering scheme [4].

Subjects and Methods:

We studied 13 healthy volunteers using an Inversion Recovery HASTE sequence (TI = 1300 ms, TE = 11 ms, echo spacing 2.7 ms, slice thickness 8 mm, slice distance 16 mm, matrix 128×128, FOV 400×400 mm²) implemented on a 1.5 T whole-body scanner (MAGNETOM Sonata Maestro Class, Siemens Medical, Germany). The dedicated iPAT surface coil system consisted of 12 coil elements (6 anterior, 6 posterior). We compared 3 different acquisition schemes: 4 coronal slices without iPAT (8 of the volunteers), 4 coronal slices with iPAT (11 of the volunteers), 6 coronal slices with iPAT (2 of the volunteers). The reference lines for iPAT were acquired immediately before the series of 80 image acquisitions (20 × air, 20 × O₂, 20 × air, 20 × O₂); the GRAPPA algorithm was used for iPAT image reconstruction (acceleration factor: 2). Respiratory triggering was implemented using a pneumatic belt, and combined with simultaneous ECG triggering; acquisition was performed in expiration. The acquisition of the 4 (or 6) slices was divided into two groups (A and B) of 2 (or 3) slices each that were acquired interleaved with respect to the inversion recovery pulses, i. e. IR_A – IR_B – ACQ_A – ACQ_B; the details of the timing algorithm are described in [4]. If the dynamically-detected RR interval (inverse of heart rate) is too long or too short for the interleaved acquisition, the sequence switches automatically to a non-interleaved scheme (IR_A – ACQ_A – IR_B – ACQ_B); in this case, the required expiration breath hold time is considerably longer. In post-processing, only images with identical diaphragm position were used to calculate the oxygen-induced signal increase.

Results:

The iPAT acceleration reduced the readout time from 214 ms without iPAT to 115 ms per slice. Figure 1 shows the decrease in acquisition time (required breath hold duration in expiration to avoid motion artifacts) as a function of the RR interval (inverse of heart rate). Maps with the relative signal enhancement in the lung of one volunteer from one multi-slice acquisition are shown in Figure 2. The mean signal increase averaged over all volunteers was 0.122 ± 0.045 with iPAT and 0.089 ± 0.027 without iPAT. We did not observe any artifacts due to the iPAT reconstruction. All examinations were performed without any adverse reactions. Total acquisition time for all 4 or 6 slices was always 80 respiratory cycles, i.e. about 8 to 14 minutes.

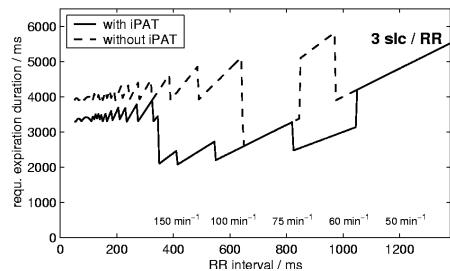
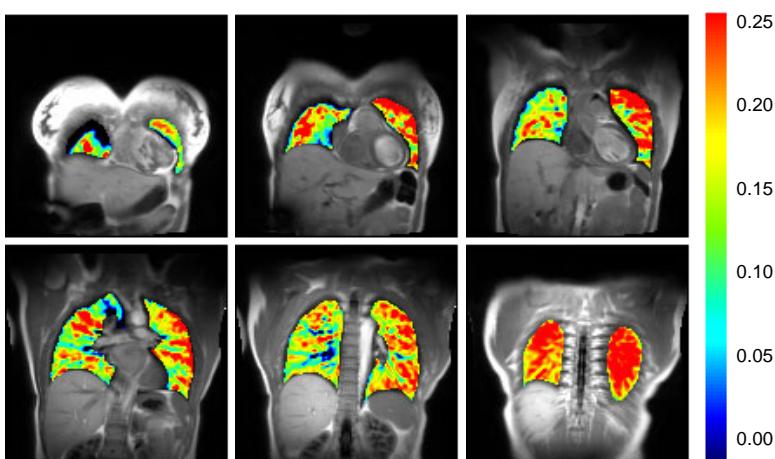


Fig. 1 ▲: Required expiration breath hold duration for 2 × 3 slices with and without iPAT, plotted as function of the RR interval (inverse of heart rate).



Conclusion:

The presented multi-slice sequence reduces the acquisition time compared with the non-iPAT sequence [4] by almost 50 %. Thus, we could increase the number of acquired slices per respiration from 4 to 6 without prolongation of the examination and, thereby, achieve a more complete coverage of the lung. We have not observed any significant difference in image quality or signal enhancement comparing non-iPAT and iPAT methods. First examinations of patients suffering from pulmonary hypertension or lung cancer using the oxygen-enhanced iPAT imaging show promising results as well.

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