Free Breathing Hyperpolarized 3He Lung Ventilation spiral MR Imaging. Implementation and validation on a clinical scanner

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Introduction: The motivations for implementing a free-breathing ventilation imaging protocol on a clinical MR scanner are two-fold. In pre-clinical studies, it is an alternative to intubation and ventilator-assisted protocols and as such facilitates the investigation of animal models in longitudinal studies. In clinical studies, it is an envisioned approach for ventilation imaging of non cooperative patients, especially neonates and pediatric patients. In this study, a free-breathing protocol for hyperpolarized (HP) ^{3}He lung ventilation imaging was designed, implemented and validated *in vivo* on rabbits.

Methods: Experiments were performed on a 1.5 T whole-body scanner with HP ^{3}He polarized at 20 %. Animals (specific-pathogen-free white rabbits, mean weight, 3 kg) were anesthetized with a ketamine-xylazine mixture. During HP ^{3}He MR acquisition, animals could breathe in and out from a 200-ml reservoir containing the gas mixture (HP ^{3}He/N_2/O_2). Spiral projection ventilation images were continuously acquired (24 interleaves, TR/TE= 50/2.5 ms, 256^2 matrix, 158x158 mm^2 FOV, and 7° flip angle) during 36s. MR signal dynamics were modeled, using an in-house software developed under Matlab, taking account of gas inflow and outflow, RF depolarization and oxygen-induced relaxation. The accuracy of the model was validated *in vitro* on a calibrated lung phantom. The model was used *in vivo* for (1) optimization of SNR and protocol parameters (flip angle, gas mixture) and (2) extraction of physiological parameters (pO_2, lung volume, tidal volume…). Time-resolved ventilation images were reconstructed using retrospective synchronization with the breathing cycle [1] and parametric maps were computed.

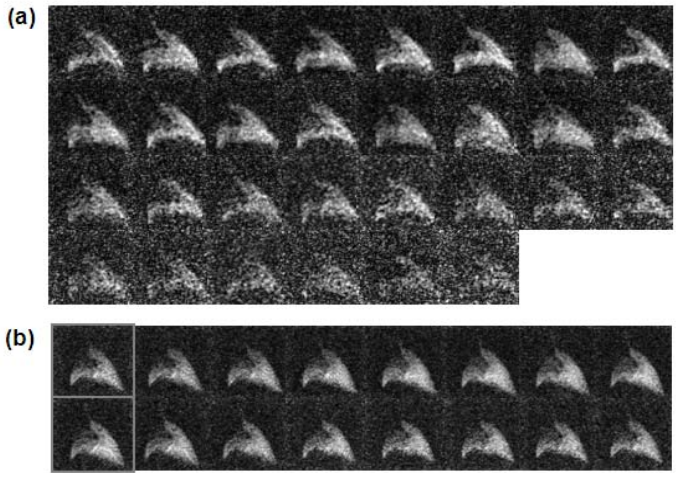

Figure 1: (a) 30 consecutive raw images reconstructed with a temporal resolution of 1.2 s and (b) Cine images reconstructed out of 26 breathing cycles (30s) with a temporal resolution of 50 ms. One breathing cycle of approximately 800 ms was split in 16 images. Framed images correspond to inspiration and expiration onset.

Results: While a temporal resolution of 1.2 s was achieved with images acquired consecutively, ventilation images retrospectively synchronized with the breathing cycle were reconstructed with a temporal resolution of 50 ms (see Figure 1). Gas volume variations and time-to-maximum maps were obtained from the time-resolved images (see Figure 2). Ventilation parameters (functional residual capacity, tidal volume, alveolar pO_2) extracted from the MR signal dynamics were in good agreement with physiological values.

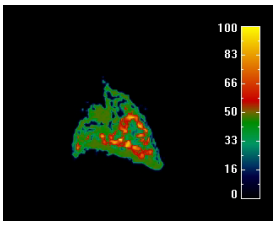

Figure 2: Parametric map of signal intensity variation (%)

Discussion and conclusion: Ventilation imaging can be performed at tidal volume using a simple experimental protocol, without any ventilation device or breath-hold period. Acquisition time, SNR and pO_2 decay can be optimized using the developed numerical model. Free-breathing ventilation images can be obtained without artifacts related to motion or gas flow. Lastly, parametric maps can be derived from the time-resolved ventilation images and physiological parameters extracted from the global signal dynamics.

References: [1] Stupar et al. NMR Biomed **20** (2007)