A 32 Channel Phased Array Lung Coil for Parallel Imaging with Hyperpolarized Xenon 129 at 3T

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Introduction: Hyperpolarized gas MRI used in combination with parallel imaging need not suffer the SNR penalty associated with reduced noise sampling since the signal can be increased by using higher flip angles [1]. Parallel imaging makes efficient use of the non-equilibrium magnetization of hyperpolarized gases since image reconstruction techniques such as SENSE and GRAPPA employ local coil sensitivity profiles to partially replace the traditional Fourier phase encoding steps. These accelerated techniques allow for shorter breath hold times in lung imaging, which is highly desirable for imaging patients with lung disease or children. In addition, the superior receiver sensitivity of the phased array coil design facilitates high SNR hyperpolarized xenon ventilation imaging. The purpose of this work was to develop and perform preliminary evaluation of a 32 channel phased array coil for xenon 129 at 3T.

Methods: The individual elements of the 32 channel phased array lung coil (Fig. 1) are composed of thick copper wire (AWG 12) and are 12cm in diameter. The wire design was found to have a superior Q-ratio ($Q_{unloaded}$ / Q_{loaded}) compared to elements cut from circuit board material [2]. The elements were tuned to the 34MHz resonance of xenon 129 at 3T. The array was built on a chest shaped former with 15 elements on the top and 17 elements on the bottom. An overlapped hexagonal design ensures nearest neighbor decoupling and adds to the low input impedance preamplifier decoupling, which is better than -35dB. Each element has one active and one passive PIN diode detuning circuit (Fig. 2), which provides better than -30dB detuning during transmit. For RF excitation a Helmholtz transmit coil was implemented, which is detuned during receive with series pin diodes. The two large loops (38cm x 40cm) are connected to a Wilkinson power divider. The transmit and receive coaxial cables contain cable traps at the xenon resonance. The coil was designed to be interfaced to a 3T Siemens Tim Trio system. Ventilation (single breath, spin density) images in 2D and 3D were acquired from healthy volunteers, who inhaled a bolus of 500-700cc hyperpolarized xenon simultaneously with a 1000cc O2/air mixture. Xenon gas was polarized using a portable prototype polarizer ("Bell", Xemed LLC) [3].

Results: Figure 3 shows a single slice from 3D TrueFISP acquisitions [4] with fully sampled k-space (acceleration factor R=1) and with R=2x3, acquired during two separate breath holds in the same volunteer. Imaging parameters were for R=1 (R=2x3): TR/TE 2.9/1.29ms (3.06/1.37ms), matrix 64x48x60, flip angle 10° (12°), resolution isotropic 6.4mm, scan time 8s (2s). The 3D reconstruction was computed offline using the 2D GRAPPA algorithm implemented in MATLAB, followed by a standard root-sum-of-squares coil combination. The GRAPPA kernel size was [1x2x4], which was capable of adequately eliminating the foldover artifact introduced by the accelerated acquisition. The fully sampled 2D GRE ventilation images shown in Fig. 4 were acquired with TR/TE 12/3.13ms, FOV 350x306mm, matrix 64x56, slice thickness 20mm, total scan time 13s. For the 2D GRE ventilation acquisition with R=3, also

Fig. 3: Single slices from 3D TrueFISP acquisitions with fully-sampled k space (left) and acceleration factor R=2x3 (right).

shown in Fig. 4, the flip angle was increased to account for the reduced number of phase encoding steps [1]. With R = 3 the total scan time was reduced to 5s. Image reconstruction for the accelerated 2D data was done online using GRAPPA. The accelerated images have comparable SNR to the fully sampled acquisition. Image slices closer to the coil elements have significantly higher SNR (factor 2-3) due to the receive profile of the surface coil receivers.

Conclusions: We have shown the first accelerated human ventilation images with hyperpolarized xenon 129 at 3T acquired using a 32 channel coil. The phased array coil enables R=3x2 acceleration which reduces the total scan time for the 3D sequence to 2 seconds without loss in SNR or resolution.
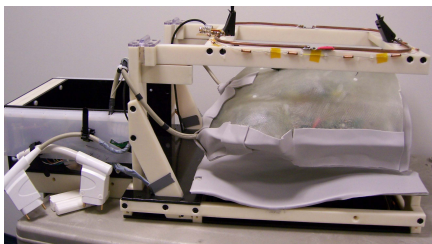

Fig. 1: 32-channel phased-array receive coil with Helmholtz transmit coil. The top array can be lifted for easy subject access.
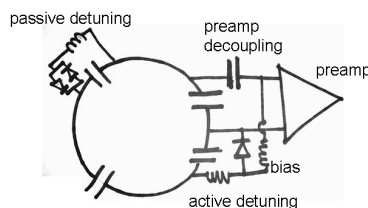

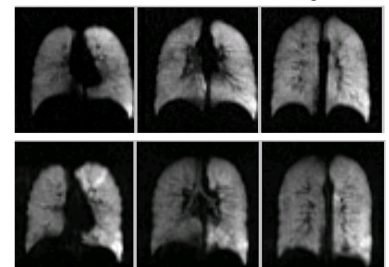**Fig. 2:** Circuit diagram for the individual receiver element.

Fig. 4: 2D-GRE ventilation images with fully-sampled k space (top row) and R=3 (bottom row) acquired in 2 different healthy volunteers.

References: [1] Mugler JP et al. ISMRM 13 (2005) 485   [2] Wiggins GC et al. ISMRM 15 (2007) 243   [3] Hersman FW et al. Acad Rad 15 (2008) 683-692 [4] Mugler JP et al. ISMRM 17 (2009), submitted