Time resolved lung ventilation volume measurement with multislice EPI using hyperpolarized 3He

K. Teh[1], S. R. Parnell[1], N. Woodhouse[1], and J. M. Wild[1]
[1]Academic Radiology, University of Sheffield, Sheffield, Yorkshire, United Kingdom

Introduction Time resolved volumetric imaging of hyperpolarized (HP) gases in the lungs has the potential to supply regional spirometric measurements which could be useful for lung disease assessment. Pulse sequences for dynamic HP gas lung imaging should be rapid to capture gas flow, and also should utilize the non-renewable longitudinal magnetization effectively in terms of SNR. To date fast low flip angle (θ‹15°) spoiled gradient-echo sequences (SPGR) have been used with a variety of sampling strategies (1-3). These have tended to image a single slice with volume coverage sacrificed in the interest of temporal resolution. A different approach is to use EPI which allows effective utilization of the polarization with higher flip angles (4). In this work multi-slice, multi-frame single shot EPI was used for ***time resolved lung volumetry*** and is demonstrated in phantom and volunteer experiments performed during expiration maneuvers.

Methods Measurements were conducted on a 1.5T whole body MRI system (Eclipse-Philips Medical System) fitted with transmit-receive circuit for ^{3}He at 48.5 MHz. Phantom studies were performed using a small quadrature T-R birdcage coil, whilst in vivo studies were performed with an asymmetric quadrature lung birdcage T-R coil. The ^{3}He gas (Spectra Gases) was polarized on site by optical pumping with Rb spin exchange apparatus (GE) to approximately 30% polarization. Phantom studies were performed on 1*l* Tedlar bag phantoms (100*ml* ^{3}He 900ml N_2) which were connected to an evacuation syringe via Tygon tubing. A single volunteer was imaged on two occasions following inhalation of a mixture of 300ml ^{3}He & 700ml N_2 from a Tedlar bag. Three different experiments were conducted **a)** comparing optimized SPGR and optimized EPI [4] for static imaging **b)** dynamic multi-slice phantom experiments during evacuation of the gas from the bag, and **c)** dynamic multi-slice in vivo studies during a relaxed expiration maneuver. **SPGR** parameters: TE=3.7ms, 64x64 matrix, TR=7 ms, slice thickness 10mm, FOV=32cm and θ_{SPGR} =11°. The **EPI** parameters were: TE=12.1ms, 64x64 matrix sampled at 0.75 of k-space in the phase direction, TR=52 ms. Static imaging comparisons were performed with the same slice and FOV as SPGR with θ_{EPI} =90°. ***Dynamic EPI*** was with relatively low θ_{EPI} =30° to preserve the polarization for later images: **(i)** phantom experiment**:** 20 slices, 7 mm thick, inter-frame time 1040ms **(ii)** low res. in vivo experiment: 18 slices, 15 mm thick, FOV=32cm, inter-frame time 936ms, and **(iii)** high res. in vivo experiment : 60 axial slices, 5mm thick, FOV=32cm, inter-frame time =3121ms. One limitation of using dynamic EPI with ^{3}He gas is signal loss due to diffusion [4] through the oscillating read gradients (G_R). The G_R is a 24 full cycle sinusoid with peak amplitude of 13mT, τ =1.208ms. With $D_{phantom}$=9x10^{-5} cm^{2}s^{-1}and $D_{in\ vivo}$=2x10^{-5} cm^{2}s^{-1} the simulated diffusion attenuation estimates attenuation of 2.8% attenuation for in vivo and 7.7% for phantom studies.

Results

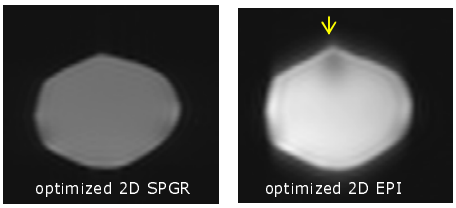

Fig.1*: SPGR phantom image and EPI from same slice. Note slight distortion due to off-resonance at the edge of the bag and some susceptibility related dephasing due to the longer effective TE.*

Fig. 2a ***2b***

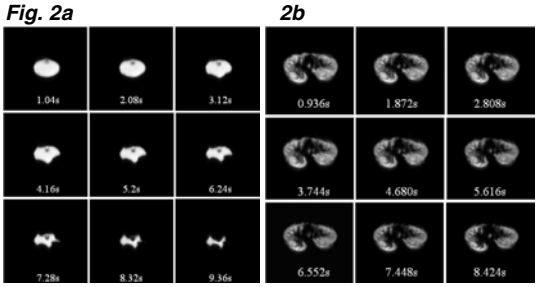

Fig.2a*: A selected slice from the dynamic phantom image time series (20 frames and 20 slices)*
& ***Fig.2b****: Dynamic in-vivo images (20 frames and 18 slices) of the first 9 frames of exhalation from total lung capacity*

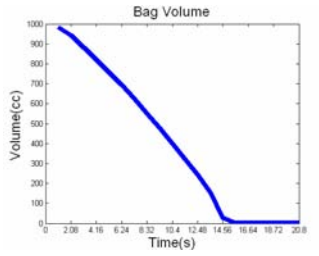

Fig.3a:*Total volume of bag*

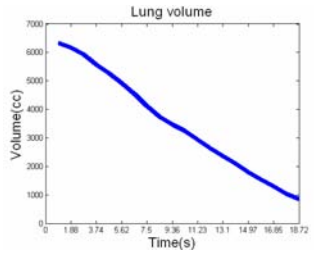

Fig.3b*:Total in vivo volume over Tacq*

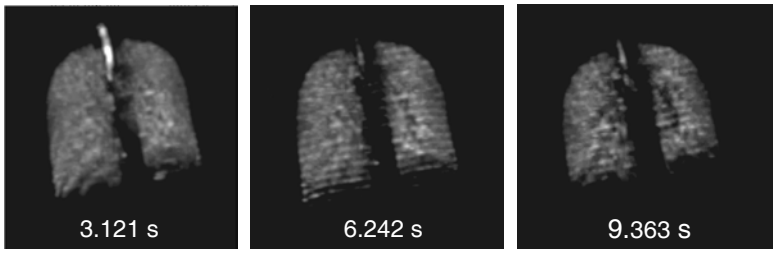

Fig.4*: High res 3D volume stack at 3s intervals during the exhalation*

a) ***Static image comparisons***: EPI shows slight blurring, some off-resonance distortions and weak N/2 ghosting artifacts (<6%), however much higher temporal resolution can be observed with the EPI image with > **8*x*** faster acquisition time than SPGR of the same nominal spatial resolution. **b,c)** Post processing of the dynamic images allows total volume determination of both the bag and lung as shown in Fig.3a and Fig.3b. Measured volume of the Tedlar bag depicted in Fig.3a shows close correspondence to the 1l volume of the bag. Fig.3b shows the time curve from the low res. in vivo data, caution is needed in the interpretation of the later time-points as exhalation of gas and RF depolarization of any residual gas contribute to the low signal intensity and low SNR prevents accurate volume measurement of the FRC. Nevertheless the *high spatial resolution* volume renders in Fig. 4 clearly demonstrate the volume-time sensitivity and show sufficient signal at the last time point to clearly segment out the ventilated lung volume.

Discussion Saam et al [4] presented a theoretical comparison of SPGR and EPI for HP ^{3}He MRI, here we have experimentally confirmed that EPI provides robust relatively artifact free images in vivo in an axial plane with high SNR. The 2D multi-slicing provides volume-time representation although the method would work equally well with a 3D EPI approach or indeed 3D gradient echo [5] with parallel imaging acceleration. Future work will involve imaging during a forced expiratory maneuver with simultaneous spirometry data collection from the MRI scanner.

References [1] Rofo Fortschr Geb Rontgenstr Neuen Bildgeb Verfahr 2000; 172:129-133 [2] Magn Reson Med 2001; 46:667-77, 2001. [3] Magn. Reson. Med 2003 49(6):991-7. [4] Magn Reson Med 42:507-514,1999 [5] Magn Reson Med. 2004;52(3):673-8.
Acknowledgement EPSRC #GR/S81834/01(P) # EP/D070252/1, GE Health, Spectra Gases, Aerosol Society UK