Single scan acquisition of hyperpolarized 3He ventilation images and ADC images using a hybrid 2D sequence

J. M. Wild[1], N. Woodhouse[1], K. Teh[1]

[1]Academic Radiology, University of Sheffield, Sheffield, Yorkshire, United Kingdom

Introduction: Measurement of the ^{3}He gas ADC with pulsed gradient methods can identify empysematous changes in lung structure at the alveolar level [1]. Ventilated airspace volumes derived from segmentation of ventilation images are also of use in identifying and quantifying obstruction [2]. In this work a ***hybrid*** 2D ***ADC-ventilation*** sequence is presented which uses low flip angles to acquire both exams in the same breath-hold. The performance of the sequence was investigated in vivo in comparison with a conventional ***2D ventilation imaging*** sequence.

Methods ^{3}He gas was polarized on site to 26% by optical pumping with rubidium spin exchange apparatus (GE Health, Princeton NJ). All work was performed on a 1.5T whole body system, tuned to ^{3}He frequency of 48.6 MHz (Eclipse –Philips Medical Systems). A flexible twin saddle quadrature T-R coil was used (IGC Medical Advances). Two healthy non-smokers performed two breath-hold exams each:

(i) A conventional ***2D ventilation imaging*** exam: Centric phase encoding, 112 views, flip angle 9°, 6 coronal slices, 15 mm slice thickness & 5mm gap, FOV =42 cm, TE=3.4 ms, TR=7 ms, 128 samples, BW ±16kHz.

(ii) The ***hybrid ADC-ventilation*** exam. This consisted of an interleaved low flip angle gradient echo acquisition with a reference (ventilation) scan (*b=0*) followed by diffusion-weighted acquisition (*b=2.89 scm^{-2}* - bipolar trapezoids of plateau strength 26.2 mTm^{-1} and duration 460 µs with 500µs ramp time –*direction in-slice*). Phase encoding was centric with 112 views (224 RF pulses in total with the interleaved sequence structure), the remaining sequence parameters were: 6 coronal slices, 15 mm slice thickness & 5mm gap, FOV =42 cm, TE=5.5 ms, TR=9 ms, 128 samples, BW ±16kHz.

The flip angle of 6°, was chosen to impart the same point spread function to the ventilation image as the 112 view ventilation only scan. These values were derived from the respective k-space filters assuming a depletion due to RF depolarization and a ^{3}He T1 of 20 s in-vivo –see Fig.1. The polarized gas was dosed differently for the respective exams according to the predicted SNR of the two respective images. For these centric encoded acquisitions, this is given by the ratio of the initial transverse magnetizations (sin 9°/sin 6°) =1.5. Therefore the ADC –***hybrid*** exam was performed with 450 ml ^{3}He and 550 ml N_2 whilst the ***standard*** ventilation only scan was performed with 300 ml ^{3}He and 700 ml N_2.The ventilation images were compared on the basis of relative SNR, prevalence of susceptibility related signal loss, spatial resolution and the segmented ventilation volume as derived by counting pixels above a threshold of 4 times the s.d. of the noise background.

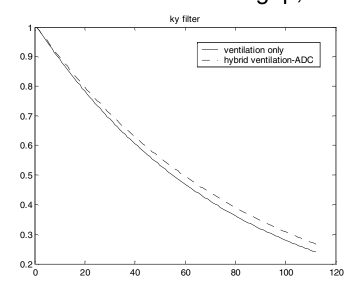

Fig. 1. k space filter of respective ventilation scans

Results and Discussion:

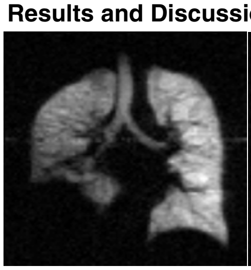

Fig. 1. Conventional ventilation image

Fig. 2. ventilation image acquired with hybrid

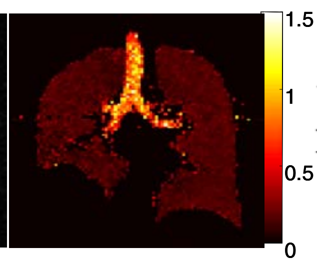

Fig. 3. High res. ADC image from hybrid sequence

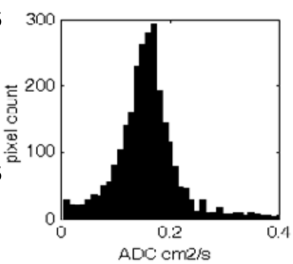

Fig. 4 ADC pixel histogram

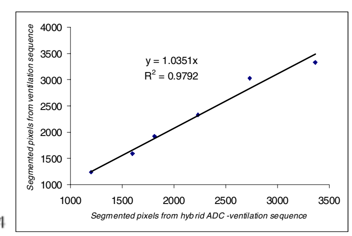

Fig. 5 Comparison of segmented volumes from same 6 slices derived from hybrid and conventional sequence

The ventilation images produced by the hybrid sequence (Fig.2) had a mean SNR of 20.8 compared to 20.3 from the ventilation only sequence (Fig. 1). The images visually demonstrated comparable spatial resolution as predicted by the k space filters of Fig.1. Susceptibility related dephasing caused by the longer TE (5.5 ms compared to 3.4 ms) only produced noticeable differences around the major vessels [3] –see arrow. When the images were segmented the two sets of ventilation volumes correlated very well –Fig. 5. In the example shown, the hybrid sequence only under estimated ventilated airspace in the slice shown in the images (5th point in Fig. 5) where the lungs are highly perfused with large vessels. This susceptibility dephasing is tolerable but could be further reduced by minimising the TE with further pulse sequence optimisation. Similarly the longer TR of the hybrid requires a longer breath-hold (12 seconds for this six slice study), despite this extended scan time the images showed no visible cardiac motion artifact when compared to the conventional scan. In conclusion, acquiring the ADC and ventilation images in one breath-hold with a hybrid sequence has provided ventilation images with comparable SNR and accurate ADC images with a high spatial resoultion. In doing so we have used 2/3 of the gas that would have been used for a dual ADC and ventilation exam and have saved the subject performing and extra breath-hold. By performing both exams in the same breath-hold, the data is inherently registered allowing quantitative cross correlation between high spatial resolution ADC and ventilation data. The prolonged exam time due to the interleaved sequence structure prevents acquisition of lots of slices with the current TR but this could be improved in the future with a shorter TR and parallel imaging techniques.

References [1] Saam, B. T.et al. (2000) MRM 44, 174-179 [2] Woodhouse N et al JMRI. 2005;21:365-369. [3] Wild JM et al, 2003, MRM. 50:417-422.

Acknowledgements. GE Health, Philips Medical Systems, Spectra Gases, EPSRC #GR/S81834/01(P).