Parallel Imaging for Short Breath Hold Times in Perfluorinated Gas Imaging of the Lung

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Purpose: To develop an MRI coil platform allowing imaging of lung function with short breath hold times using perfluorinated gas mixed with oxygen that will also allow ^{1}H imaging without removing the coil and changing the subjects physical position. This should be of interest to clinicians and imaging scientists studying lung function.

Introduction: Although parallel imaging has had a significant impact in clinical imaging using 1H MRI, the impact on nuclei other than hydrogen has been substantially less. While there are several reasons two major issues are the lack of a 'body' transmit coil for frequencies other than 1H and the fact that the signal source is often much lower than for conventional hydrogen imaging. In this specific application for lung functional imaging using a Perfluoropropane/oxygen mixture, the concentration of the PFP in the lung is approximately *250 mMolar* compared 10's of molar concentrations for hydrogen based imaging. The practical consequence for parallel imaging is that the target acceleration factors will be far less than for clinical imaging, thus the number of coil elements will be less.

Methods: In this project, we chose a modest goal, 8 receive elements with the requisite separate transmit element for imaging 19F as well as a means to disable the coil for body coil imaging of 1H for anatomic reference images. The Duke group worked with the scientists and engineers at ScanMed to achieve a prototype for bench and phantom testing finalizing with a working prototype for ongoing clinical trials at Duke. Comparison mages were obtained on a Siemens Trio (19F @ 115.9 MHz) using a GRE-VIBE sequence (TR/TE/Flip Angle 13ms/1.6ms/70°), 64x64x18 (6.25mm x 6.25 mm x 15 mm) with a scan time of 15 seconds. Images are compared at steady state.

Results: Phantom tests (annular phantom containing the 79%/21% PFP/Oxygen mixtures) showed average SNR for the T/R coil of 55.8 compared to 56.7 for the array coil or approximately equal. Based on bench testing and phantom scans the coil was incorporated into ongoing studies. One subject that had been scanned in the original proof of concept study in 2010 returned ~ 4 years later with similar pulmonary function tests in a subsequent study using the same protocol but with the new array coil. The images on the left in figure 1 were obtained from a subject with COPD (71 y/o male, ex-smoker, 50 pk-years, FVC 3.48, FEV1 2.23, FEV1/FVC .64) in the first feasibility study in 2010 using a commercial Quadrature T/R vest coil at 3T of the same design used in many hpMRI studies obtained from Clinical MR Solutions, Brookfield, WI. The images on the right were obtained from the same subject in a subsequent study in 2014 (FVC 3.26, FEV1 2.04, FEV1/FVC .63) using the 8 element array coil (ScanMed, Omaha, NE) at 3T (Scan Parameters are identical). Note the improved SNR, signal homogeneity and anatomic coverage (in particular note the major airways visualization in the superior aspect of the image). SNR was determined in each data set using BG noise (SD) and mean signal from the same anterior, middle and posterior slices (Osirix, V5.6, Pixmeo, Geneva, Switzerland). For the T/R coil the SNR was 31.1, 16.3 and 6.4 compared to the array coil with SNR of 41.7, 20.3 and 22.8 for an average of approximately 60% improvement. Figure 2 shows an example of washin-washout images in one slice of another subject with severe COPD (79 y/o male, ex-smoker, 25 pk-years, FVC 4.00, FEV1 1.34, FEV1/FVC 0.34) obtained using the array coil with a scan time of 5.62 seconds per 3D image.

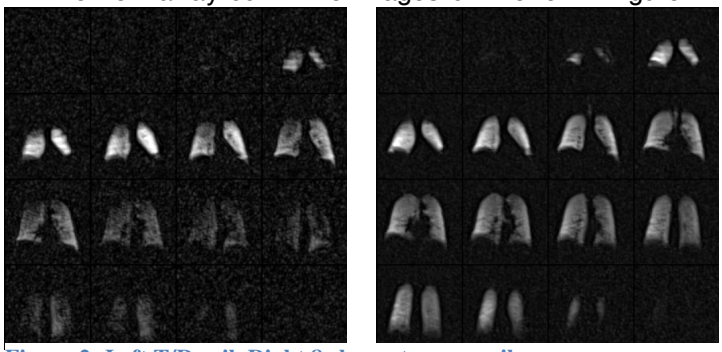

Figure 2: Left T/R coil Right 8 element array coil.

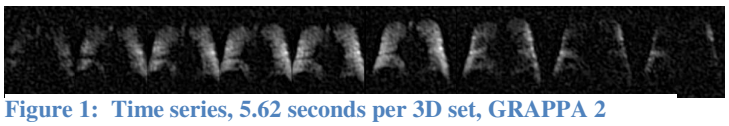

Figure 1: Time series, 5.62 seconds per 3D set, GRAPPA 2

Discussion: The array coil performs better than the earlier transmit/receive coil with better S/I coverage, better image uniformity and better SNR in patient studies. It has allowed implementation of modest acceleration with reasonable image quality.

Conclusion: Given with the goal of shortening the breath hold times, implementation of parallel imaging with an 8 element array coil and dedicated transmit coil has provided good image quality even in subjects with severe lung disease with 3D imaging times < 6 seconds.

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