Assessing and Correcting Respiration Induced Variation of B1 in the Liver

F. Padormo[1], S. Malik[1], J. V. Hajnal[1], and D. J. Larkman[1]

[1]Robert Steiner MRI Unit, Imaging Sciences Department, MRC Clinical Sciences Centre, Hammersmith Hospital, Imperial College London, London, United Kingdom

Introduction: It has been shown that the B1 inhomogeneities in high field systems (e.g.7T) can severely compromise image quality. B1 inhomogeneities are still significant at 3T, but generally do not destroy the ability to image. However, the variations in flip angle (and hence contrast) across the field of excitation can still cause significant problems, particularly with applications where absolute quantification is required. These observations have lead to the concept of B1 shimming, where multi-port transmit coils are driven in such a way as to correct the B1 inhomogeneity. The first generation of such approaches have generally assumed that the B1 shim is a temporally invariant quantity and depends only on the subject. However, there have been some recent observations ([1], [2]) which indicate that the B1 field is dependent on physiological parameters. Here we map the B1 field generated by a whole body transmit coil array during inhale and exhale breathholds across a number of subjects and assess the variability in B1 field within the liver (a target frequently imaged for quantitative analysis [3]) . We demonstrated that B1 shimming on an 8 channel body system could correct for variations in the B1 field between these two states.

Methods: All subjects were scanned with local ethical approval (Ethics Numbers: 08/H0711/82 & 08/H0706/74). B1 mapping was performed using the AFI [4] approach. A single transverse slice centered on the liver was imaged in each subject. Data was acquired with the following parameters: voxel size: 15x7x15mm, FOV: 309x450mm, TE=4.6ms, TR1=30ms and TR2=175ms, resulting in a 5 second breathhold. Higher resolution, longer breathhold scans (voxel size = 7x7x7mm, scan time = 10s, other parameters constant) were also acquired for comparison. B1 maps were then generated in MATLAB (The Mathworks, USA). Four subjects were scanned with one subject scanned three times, leading to six examinations in total. Each examination consisted of either five or ten B1 maps at maximum inhale and exhale. The scans were performed as dynamic acquisitions with pauses between each scan for breathhold instruction. A dynamic loop was chosen for each breathhold state to prevent any scanner dependent rescale (either RF power or receiver gain optimization) between measurements. Initial automated scanner calibration was performed with the subjects free breathing. Two nested regions of interest were drawn in the liver and the variation between the average inhale and exhale maps explored. For the shimming experiments, a single subject was scanned to obtain B1 maps with the low resolution scan outlined above. TR1 and TR2 were reduced to 20ms and 117ms respectively in order to allow all eight coils to be mapped in 25s for each breathhold state whilst keeping their ratio constant. The method described in [5] was used in conjunction with AFI to produce the B1 maps for each coil in each breathing state. For this shimming experiment RF power calibration was performed fully for each state prior to B1 mapping to correct global RF power changes before attempting shimming. Using Magnitude Least Squares optimization [6], the drives and optimized maps for the inhale and exhale states were then calculated and compared in a ROI over the liver.

Results: The low and high resolution B1 maps displayed the same properties and so the data presented includes both sets of scans. When all subjects and scans were combined the mean variation in flip angle between inhale and exhale states in the larger and smaller regions were $\Delta\theta = 4.3 \pm 0.6°$ and $\Delta\theta = 4.8 \pm 0.8°$ (both with significance levels of $p<0.001$) respectively. Reproducibility within subjects was high but, as expected, varied significantly between subjects. Figure 1 shows example ROI averages of ten inhales and exhales for two subjects A and B. These subjects respectively represent the largest and smallest difference between inhale and exhale states. Subject A shows an average change of $\Delta\theta = 9.6 \pm 2.6°$, whilst subject B shows a change of $\Delta\theta = -0.1 \pm 0.7°$. Figure 2 shows an example source image formed at TR1 showing the locations of the ROIs (overlaid) and the difference (colour map on r.h.s. in degrees) of B1 between inhale and exhale for subject A. There is a global mean offset but also significant structure change within the difference map, a feature typical of all subjects. This indicates that a global RF power change will not fully compensate for this difference. In the B1 shim experiment, the mean flip angle and standard deviation inside a ROI was calculated for the measured B1 maps and shim-corrected cases in order to assess the change in inhalation states and the improvement the shim provides. The mean difference between states was approximately 0.7° for both the measured and shimmed scenarios (reflecting the RF power optimisation allowed between these two experiments). However, the standard deviation across the ROI drops from 1.61° to 0.97° (reflecting the impact of a spatially varying shim).

Conclusions: We have shown that B1 fields do vary significantly in the liver during the respiratory cycle at 3T. This can lead to errors in quantitative methods which rely on accurate knowledge of net flip angle. Two approaches could be taken to mitigate this: preemptive RF shimming or post acquisition correction (based on B1 maps). Either approach requires an estimate of the B1 field variation during the respiratory cycle. The approach used here to map the extremes of the respiratory cycle could be combined with interpolation to generate B1 through the breathing cycle. Alternatively, retrospective respiratory gating could be used to directly map B1(t). We have demonstrated that a significant correction can be made by global RF power scaling (the B1 shimming experiment allowed global scaling between states) which reduced the flip angle variation from a group mean of 4 degrees to 0.7 degrees for this individual. Further improvement requires correction of local variations in B1, which can be achieved by RF shimming. This reduced the standard deviation across the ROI from 1.6 to 1 degree. This demonstrates that B1 measurement is likely to be important for quantitative liver imaging and that pre–emptive RF shimming combined with global respiratory cycle dependent RF scaling may provide a mechanism of control.

Acknowledgements: MRC Clinical Sciences Centre for grant funding. **References**: [1] Gaesslin, I. et al. (2008) ISMRM 16:202; [2] Sung, K. & Nayak, K. (2008) JMRI 27:643–648; [3] O'Regan et al. (2008) Radiology 247 (2): 550; [4] Yarnykh VL. (2007) MRM 57:192-200; [5] Nehrke, K. & Börnert, P. (2008) ISMRM 16:353; [6] Kassakian, (2006) UCB PhD Thesis

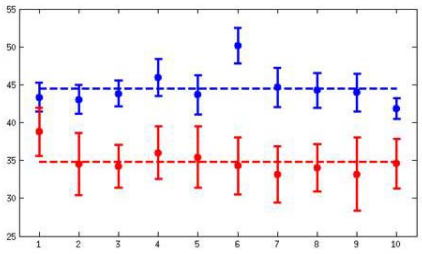

Fig 1a – Subject A's average flip angle in a ROI over 10 scans. Blue = Inhale, Red = Exhale.

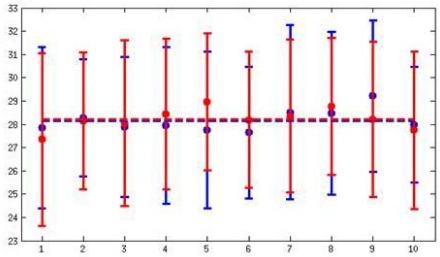

Fig 1b – Subject B's average flip angle in a ROI over 10 scans. Blue = Inhale, Red = Exhale.

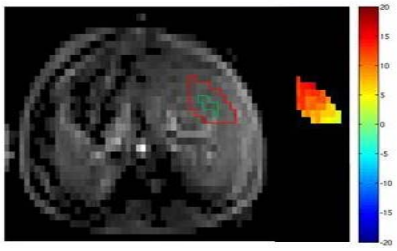

Fig 2 - Example ROIs and in color on the r.h.s. the difference between the average B1 maps over this region.