Interleaved T1- and T2*-weighted Imaging Can Evaluate Dynamic Oxygen Challenge: A Feasibility Study

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INTRODUCTION

Dynamic oxygen challenge evaluated by nuclear magnetic resonance T_1 and T_2* relaxation times (DOCENT) is a robust non-invasive prognostic test that reveals tumor hypoxia (1,2)., It accomplishes this by exploiting tissue oxygenation level dependent (TOLD) and blood oxygenation level dependent (BOLD) MRI contrast techniques that assess tumor oxygenation in vivo. Currently, no effective simultaneous T_1- and T_2*-weighted dynamic acquisition method has been developed for clinical applications at 3 Tesla field strength.. It has been shown previously (3) that a two point 3D modified fast inversion recovery method can provide T_1- and T_2-weighted images simultaneously in a short scan time. However, the technique lacks acquisition of T_2* information, which is essential for the study of the BOLD effect. An interleaved T_1 and T_2* approach was presented by Winkelman, et al in brain studies at 1.5T, although this apparently did not work well for abdominal exams performed at higher field-strength. Therefore, a fast 2D respiratory-triggered interleaved T_1- and T_2*-weighted sequence, capable of monitoring BOLD and TOLD effects simultaneously, has been developed and tested on the human spleen and kidney.

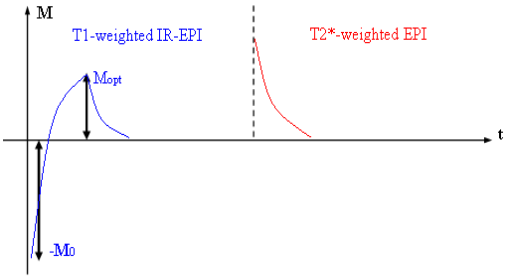

Fig.1.Schematic plot - Interleaved T_1W and T_2*W sequence.

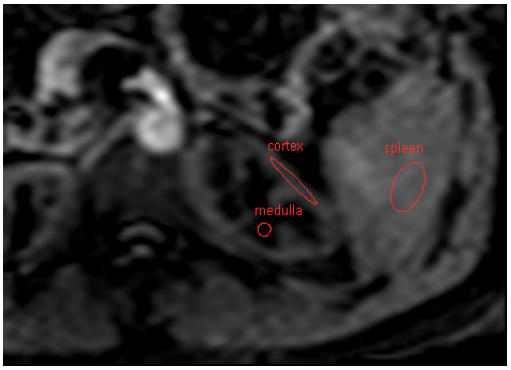

Fig. 2. T_1-weighted image with ROIs

METHODS

Imaging has been performed on a clinical 3.0T scanner (Achieva, Philips Medical Systems) using a SENSE cardiac coil (6-element). A 2D T_1-weighted inversion recovery echo planar imaging (IR-EPI) experiment has been fused together (interleaved) with a T_2*-weighted EPI sequence (Fig. 1). For the T_1-weighted imaging, the optimum TI was set at 1400ms with TE = 5.6ms (4). The TE value of the T_2*-weighted portion was equal to 26ms. All other parameters for both sequences were identical (TR ~ 2 respiratory cycle, FOV=25cm, matrix size=128✕128, slice thickness=5 mm, partial Fourier acquisition factor=0.625, SENSE factor=2, multi-shot, SPIR fat suppression). The FOV was selected to include spleen, left kidney, and paraspinal muscle (Fig. 2). Measurements were acquired during gentle breathing with respiratory triggering. Total scan time for each T_1-weighted and T_2*-weighted images was around 24s. Ten baseline measurements were collected while breathing room air, followed by 20 measurements during inhalation of 100% oxygen. The first *in vivo* experiments were conducted in 3 volunteers.

RESULTS

Three regions of interest (ROI) were drawn by Y.D. (Fig. 2), and dynamic BOLD (Fig.3) and TOLD (Fig. 4) effects with ~24 sec temporal resolution were generated from interleaved T_2*- and T_1-weighted dynamic images. Both spleen and renal cortex showed large increases in T_1-weighted signal intensity (mean maximum Rel. Signal Change (%) = 16.9 ± 4.8 and 10.8 ± 3.0, respectively), whereas renal medulla showed little TOLD response (mean maximum Rel. Signal Change (%) = 0.7 ± 6.6). Conversely, only renal medulla showed a large BOLD effect (mean maximum Rel. Signal Change (%) = 14.3 ± 3.9). A different pattern of BOLD response was observed in spleen and renal cortex, minimal in both (mean maximum Rel. Signal Change (%) = 0.3 ± 1.7 and 1.2 ± 3.1, respectively)

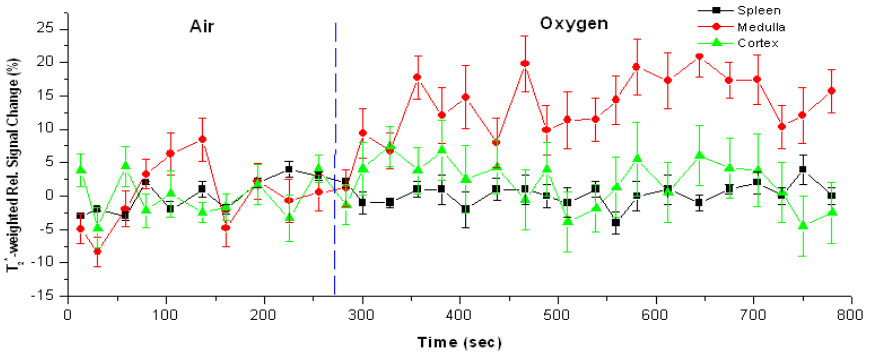

Fig 3. Changes in relative signal in response to 100% oxygen breathing in BOLD for spleen and kidney.

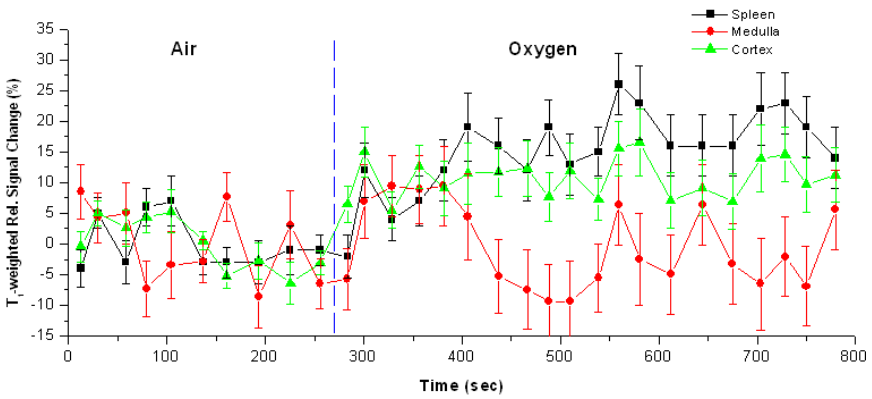

Fig 4.(right) Changes in relative signal in response to 100% oxygen breathing in TOLD for spleen and kidney.

DISCUSSION AND CONCLUSION

This study has shown that the present 2D respiratory-triggered interleaved T_1- and T_2*-weighted sequence provides a promising means to study TOLD and BOLD response simultaneously without the need for registration and with good temporal resolution (less than 30 seconds). Our observation of TOLD (but no BOLD) response in spleen, confirms that reported previously by O'Connor at al at 1.5T (6). This method also has the potential to calculate T_1 and T_2* maps with multi-echo acquisition applied (3).

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ACKNOWLEDGEMENT

Supported in part by The Mary Kay Ash Foundation