Assessment of liver oxygenation with BOLD MRI at 3T. Feasibility study

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Introduction

Liver biopsy is the gold standard for the liver fibrosis evaluation in patients affected by chronic liver disease. In healthy livers the vascular input is provided by the portal vein and hepatic artery, with the portal vein representing the main source of blood supply and normally the oxygenation of the liver is carefully auto-regulated. As hepatic fibrosis progresses it is thought the liver parenchyma become hypoxic which drives an increase in the relative arterial supply which has been observed with many different techniques.

Blood oxygen level-dependent (BOLD) MRI is a non-invasive diagnostic method for assessing tissue oxygenation, by detecting signal changes in oxygenation secondary to changes in blood flow [1]. Several animal studies have demonstrated significant changes in tissue T2* (decrease in R2*) in response to modifying O_2 concentrations in several organs [2-6]. In normal liver this type of response has not been observed or expected owing to the dominant portal supply and the autoregulation mechanism. Pilot work indicates that changes may be observed using this technique in cirrhotic patients with hepatocellular carcinoma [7]. BOLD imaging in the liver is challenging owing to the problems of respiratory and vascular motion. The aim of this work is to develop a R2* based imaging technique with acceptable variability that can be used for pre and post oxygen challenged studies in patients.

Methods

Seven healthy volunteers (6 male, 1 female, mean age 37 ± 9 years ranging from 28 to 56 years) with no history of GI, hepatobiliary or cardiovascular disease and not receiving any regular medication were recruited. All volunteers fasted for 8 hours prior to their study. Imaging was performed using a whole body 3T MRI system (Signa HDx, GE Healthcare, Milwaukee, USA) with an 8 channel cardiac receive coil before and after inhalation of pure oxygen.

A multi-echo fast gradient echo sequence was used - ETL:10, TE:2.3/6.9/11.5-43.7ms, TR:46ms, Flip:15°, Matrix:192x96, ASSET:2, BW:62.5KHz, FOV: 35cm (80%), slice thickness:8mm. The sequence was modified for multi-phase ET operation and respiratory triggering. Five sagittal slices were prescribed in the mid liver. An initial breath-held dataset was acquired without oxygen. Next, a free-breathing gated 10 min acquisition was performed. After 2 minutes into this sequence, oxygen was delivered at 10L/min via facial mask. Before the oxygen was removed, another breath-held (BH) dataset was acquired. The BH acquisitions ensured 'pre-' and 'post-' datasets free of breathing artefact.

R2* maps were generated for the pre and post data sets using local software. ROIs were placed over the liver to measure the mean and standard deviation (table 1). Liver vessel contributions were removed by using a minimum-error threshold to isolate the parenchyma [8].

Results

Table 1. R2* measurements

R2* Whole liver measurements.								
	Pre O2			Post O2				
	Mean	SD		Mean	SD		ΔMean	Δ SD
S1	79.64	19.82		80.15	20.74		0.51	0.92
S2	57.00	17.78		54.89	20.53		-2.11	2.75
S3	67.94	15.15		70.01	16.42		2.07	1.27
S4	62.50	12.36		62.30	13.86		-0.20	1.50
S5	42.52	9.04		42.96	9.19		0.44	0.14
S6	64.68	10.72		65.24	11.24		0.56	0.52
S7	43.49	9.66		42.59	11.65		-0.90	1.99
R2* Thresholded liver parenchyma measurements								
S1	63.12	14.83		55.53	11.60		-7.59	-3.22
S2	52.09	12.94		53.32	13.84		1.23	0.90
S3	50.33	12.76		49.85	12.05		-0.48	-0.71
S4	51.39	10.19		49.88	9.13		-1.51	-1.06
S5	35.75	4.45		36.48	3.72		0.73	-0.73
S6	56.86	9.17		55.51	8.95		-1.35	-0.21
S7	37.06	6.62		38.68	6.61		1.62	-0.01

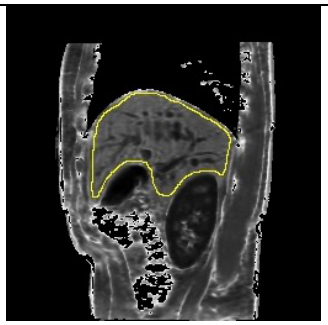

Figure 1: The ROI on the post-O2 R2* map

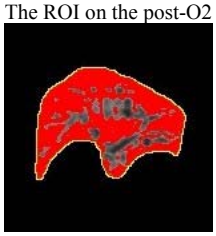

Figure 2: The thresholded parenchyma

There was no significant increase in R2* values in the whole liver or parenchyma

Conclusion

This preliminary work to develop a robust 3T BOLD imaging based oxygen challenge method for the liver has demonstrated that it is possible to obtain consistent R2* difference results in volunteers with normal liver with a low degree of variability. As expected in volunteers no difference in R2* was observed pre and post oxygen challenge. This has been achieved using both a breath-held and respiratory triggered method and enhanced by the use of a minimum error based thresholding approach to reduce the impact of vascular signals on the R2* map and delta R2* calculation. Studies in patients with chronic liver disease and hepatic tumours are planned using this methodology. This will include use of the multiphase dataset to study the time course of the BOLD effect.

References

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