Extracting arterial to portal hepatic flow ratio using high frame rate Gd MRI

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Introduction: On time-resolved contrast enhanced MRI, a cirrhotic liver tends to enhance less and more slowly than the normal liver. In addition, it is well known that the ratio of arterial to portal blood supply for the liver increases in cirrhosis. In previous approaches, a separate 2D contrast enhanced exam was necessary to sample the liver enhancement curve with high temporal resolution, complicating the integration of this method into clinical practice. We hypothesize that these differences in liver perfusion between normal and cirrhotic liver can be detected using a high frame rate 3D contrast enhanced MRI of the liver obtained with the TRACER[1] method.

Methods: De-identified contrast enhanced liver data from 28 clinically evaluated subjects (14 normal, 9 fibrotic, 5 fatty liver) were obtained by performing a TRACER reconstruction on 3D stack of variable density spiral acquisitions. The 14 normal subjects were liver donor candidates whose liver health was verified clinically. For all fibrotic subjects, fibrosis score from biopsy and trichrome stain were available. Fibrosis grade was greater than 3 (on a scale from 0-4) for all subjects and five subjects had grade 4 fibrosis (cirrhosis). Data were acquired at 1.5T (GE signa EXCITE) using a cardiac coil and a 3D spiral acquisition during bolus injection of 10 ml gadoxetate. Imaging parameters: TR/TE/flip = 6/0.6/15, FOV=36-46 (depending on patient size), matrix = 256x256x36-56, bandwidth = ±125kHz, 48 spiral leaves for a fully sampled volume. 3D volumes were reconstructed at a ~4 frames per second temporal frame rate using TRACER[1]. Region of interest analysis was used to obtain graphs of signal intensity (SI) versus time for aorta, portal vein, spleen, and liver parenchyma. A sliding window (10 seconds) of data was used to compute the slope along the liver parenchyma curve for all time points using a linear least squares fit. The peak aortic enhancement was taken as the end of the arterial and beginning of the portal venous phase. The maximum slope before this peak (A_{max}) and after the peak (P_{max}) was computed. The hepatic perfusion index[2] (HPI = A_{max} /(P_{max} + A_{max})) was computed.

Results: Measured parameters for healthy, fibrotic and fatty livers are shown in Table 1. The slope ratio for the fibrotic and fatty liver groups is significantly different than the healthy liver donor group (p-value = 0.003 and 0.02 respectively). This difference is visually striking in the SI curves plotted in Fig. 1. For the cirrhotic, the maximum liver parenchyma curve slope is similar for both arterial and portal phases. However, for the normal liver, the maximum slope during the portal phase is significantly more than the arterial phase.

Discussion/Conclusion: These data, extracted from a 3D spiral time-resolved acquisition used for routine dynamic contrast enhanced liver MRI, show a trend of increased arterial and decreased portal phase slope in cirrhosis reflecting the increased arterial supply and decreased portal supply to the cirrhotic liver. This matches our expectation for liver perfusion changes in cirrhosis and inflammation. In traditional HPI calculations, peak spleen enhancement is used to distinguish between arterial and portal phases.[2] However, for several subjects in this study, peak spleen enhancement occurred significantly after the beginning of the portal phase. We used the peak aortic enhancement to divide the two phases because, (1) it properly divided cases having a "late" spleen enhancement and (2) the aortic peak is more consistent which lends itself to a more automated determination. The HPI ratio trends and reaches statistical significance. The HPI is also reduced for fatty liver cases as well.

References: [1] Xu et al. MRM 2013;69:370-381. [2] Miles K, et al. Radiology 1993;188:405-411.

	Donor (n=14)	Fibrosis (n = 9)		Fatty Liver (n = 5)	
	$\mu \pm \sigma$	$\mu \pm \sigma$	p-value	$\mu \pm \sigma$	p-value
Arterial Phase Slope (A_{max})	0.7 ± 0.8	1 ± 1	0.3	1 ± 1	0.2
Portal Phase Slope (P_{max})	2 ± 1	1 ± 1	0.2	2 ± 1	0.5
Hepatic Perfusion Index (HPI)	**0.2 ± 0.1**	**0.4 ± 0.1**	**0.003**	**0.4 ± 0.1**	**0.02**
Time btw PV and aorta peak	13 ± 4	18 ± 8	0.05	15 ± 8	0.4
Time btw spleen and aorta peak*	6 ± 3	7 ± 3	0.3	10 ± 5	0.05

Table 1. (* where available, μ denotes mean, σ denotes standard deviation)

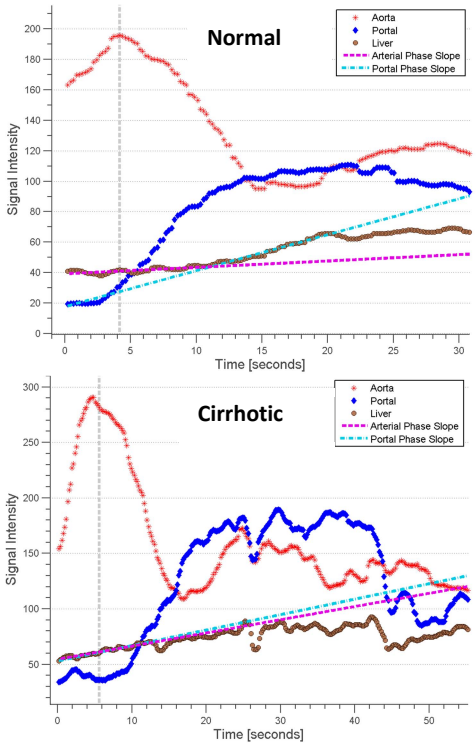

Fig. 1 SI plots for a normal and cirrhotic liver are plotted. Gray dashed line denotes time of peak enhancement in the aorta.