Quantification of hepatic perfusion fraction using diffusion-weighted imaging with multiple b-values: utility for the diagnosis of liver cirrhosis

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Introduction: There is data suggesting that hepatic apparent diffusion coefficient (ADC) is decreased in patients with liver fibrosis and cirrhosis, however with some degree of overlap between normal and cirrhotic liver [1]. It has been shown in other models that DWI provides simultaneous diffusion and microcirculation information provided these two parameters can be separated [2]. Since liver perfusion is affected in advanced liver fibrosis and cirrhosis [3], the objective of our study was to develop a non contrast method based on SS EPI DWI for the estimation of advanced diffusion parameters, including ADC and perfusion fraction (PF), for the diagnosis of cirrhosis.

Methods: DWI was prospectively obtained on 7 cirrhotic patients and 7 patients with normal liver at 1.5T. All subjects underwent free breathing or respiratory triggered SS EPI DWI (using 9 b-values, 0, 50, 100, 150, 200, 300, 500, 700 and 1000 s/mm^2). Post processing analysis of DWI included: ADC^{Total} (using all b-values), true diffusion coefficient (ADC^{High}) (using b> 200) and PF (in %). PF was calculated as PF = (SI$_0$-SI$_{int}$)/ SI$_0$ where SI$_0$ is the measured SI (signal intensity) for b0, and SI$_{int}$ is the y intercept point of a linear curve fit equation generated from ADC^{High}. Each diffusion-weighted dataset was derived from a large ROI in the right hepatic lobe. Spatially resolved maps of the diffusion parameters were also generated and compared qualitatively with ROI results.
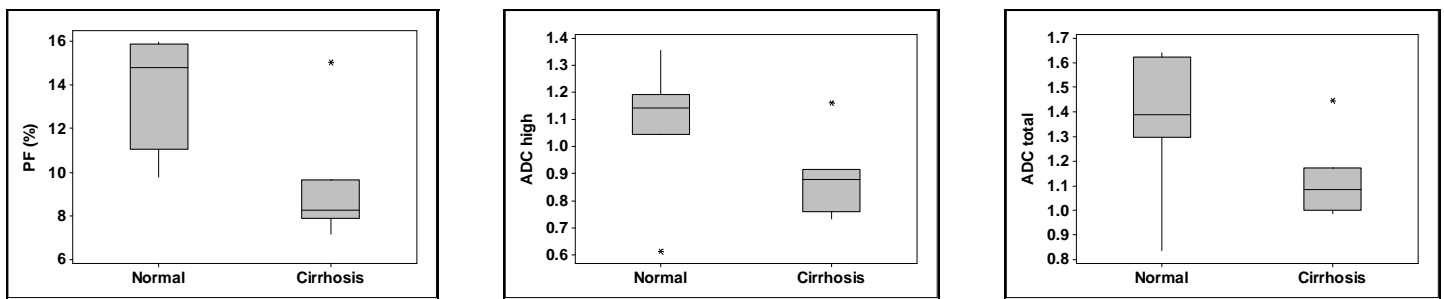

Figure 1: Box plots of diffusion parameters (PF-left, ADC^{High}-middle, and ADC^{Total}-right) in normal and cirrhotic livers (top and bottom of the boxes represent 25-75% percentiles, line in the box represents the median value)

Results: Liver ADC^{Total} and ADC^{High} (x 10^{-3} mm^2/sec) were lower in cirrhosis (1.12 ± 0.16 and 0.88 ± 0.14) compared to normal liver (1.36 ± 0.27 and 1.09 ± 0.14) without reaching significance (p=0.09). Liver PF (in %) was significantly lower in cirrhosis compared to normal liver (9.28 ± 2.66 vs. 13.47 ± 2.56, p=0.01), with almost no overlap between normal and cirrhotic livers **(Fig. 1)**. **Fig. 2** shows example parametric maps for the diffusion metrics for a normal subject and cirrhotic patient. Quantitative values in each case are consistent with large ROI group analysis. Sensitivity, specificity, PPV and NPV for the diagnosis of cirrhosis are listed in **Table 1**.

	PF (< 9.7%)	ADC^{Total} (<1.2)	ADC^{High} (<1.0)
Sens.	0.857	0.857	0.857
Spec.	1.0	0.857	0.857
PPV	1.0	0.857	0.857
NPV	0.875	0.857	0.857

Discussion: ADC has been shown to correlate with liver fibrosis and inflammation [4]. Our results demonstrate that the cirrhotic liver has a lower ADC^{Total} when compared to normal, consistent with previous studies [5]. Furthermore, we established the utility of PF to diagnose cirrhosis, which is likely a reflection of the perfusional changes occurring during cirrhosis. The use of DWI has the potential to serve as a marker for liver perfusion changes and predict advanced liver disease, useful for diagnosis, prognosis and follow-up of patients with chronic liver disease. Future studies are aimed at correlating PF obtained with DWI and perfusion changes observed with dynamic contrast-enhanced imaging.
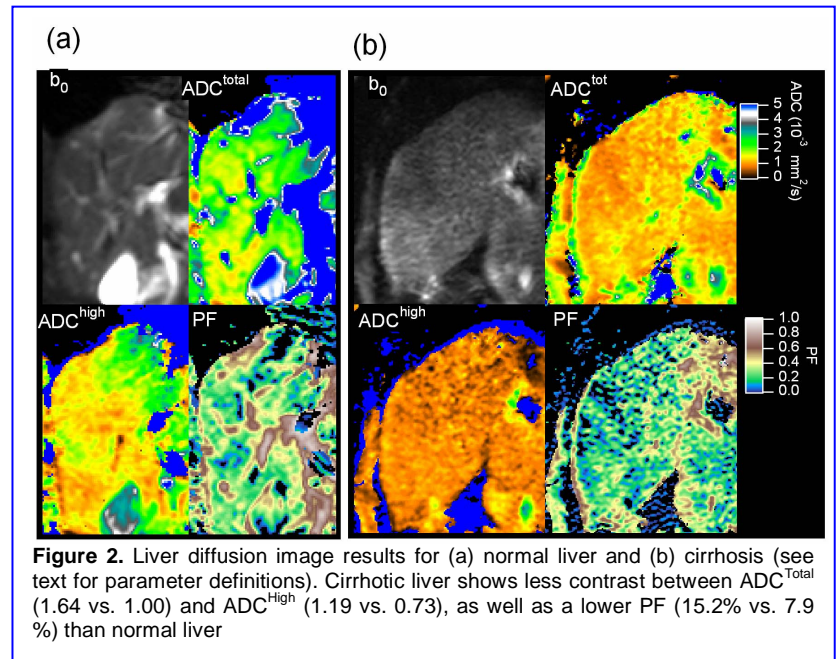

Figure 2. Liver diffusion image results for (a) normal liver and (b) cirrhosis (see text for parameter definitions). Cirrhotic liver shows less contrast between ADC^{Total} (1.64 vs. 1.00) and ADC^{High} (1.19 vs. 0.73), as well as a lower PF (15.2% vs. 7.9 %) than normal liver

References
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5. Lewin M, et al. Hepatology 2007