Characterization of liver cirrhosis with a dual-input perfusion model

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Cirrhosis is a diffuse hepatic parenchymal process characterized by fibrosis and nodular regeneration. A recent study used a single slice sequence *(1)* to demonstrate a good correlation between hepatic flow parameters and the degree of cirrhosis. We have applied a dynamic contrast enhanced 3D perfusion MR imaging sequence, with anatomic coverage of the entire liver, to evaluate patients with liver cirrhosis and a control population. A compartmental model (*2*) was used to measure both arterial and portal venous flow rates and to determine perfusion parameters that best discriminate cirrhotic from non-cirrhotic liver.

Methods

Liver perfusion MRI was performed on 11 cirrhotic patients (7 men, 4 women, ages 54.8±6.6 y) and 12 controls with non-cirrhotic liver (7 men, 5 women, ages 53.8±13 y). 3D whole-liver T1-weighted TurboFLASH volumes (Fig. 1) were acquired continuously every 3.4 sec for a total of 100 secs after injection of 8 mL Gd-DTPA at 5mL/sec. Dynamic images were acquired at 1.5 T (TR/TE/FA 3.2/0.8/9º, 128 x 256x40 matrix, 40 cm FOV, 18 cm coronal slab). Coronal-plane imaging minimized flow-related enhancement of the aorta, as substantiated by imaging two subjects and a flow-phantom in both the coronal and axial planes.

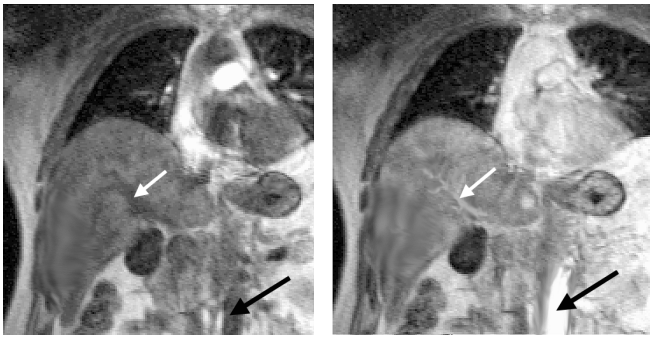

Figure 1. Aorta (black arrow), portal vein (white arrow), and the liver at 7 sec (left) and 17 sec (right) after injection. Shown is one coronal view from a dynamic 3D acquisition.

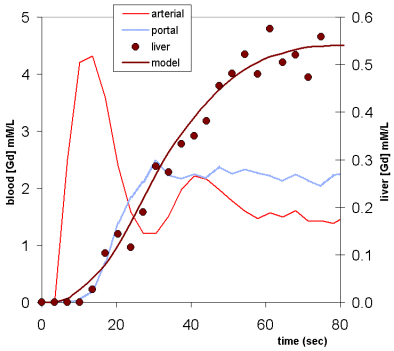

Figure 2. Concentration-time curves in a normal patient. The aorta and portal vein are plotted on the left y axis. The right y-axis plots the liver uptake (dots) and the best fit dual-input model.

Time activity curves were obtained by sampling of signal in the abdominal aorta, portal vein, and liver parenchyma (Figs 1,2). Gd-DTPA concentration was derived from the signal intensity and the resulting data were fitted to a dual-input one-compartment model

$$C_L(t) = \int_0^t \left[k_{1a} C_a(t'-\delta) + k_{1p} C_p(t')\right] e^{-k_2(t-t')} dt'$$

where $C_a(t)$, $C_p(t)$ and $C_L(t)$ represent the concentrations of contrast in the aorta, portal vein and liver respectively; δ represents the transit times from the aortic region to the liver, k_{1a} represents the aortic inflow rate constant, k_{1p} the portal venous inflow rate constant and k_2 the outflow rate constant. Input rate constants were converted to arterial F_a and portal F_p flows. Arterial fraction was defined as $A\% = 100 \cdot F_a/(F_a + F_p)$. The distribution volume D of the contrast agent through the liver compartment was calculated as $D\% = 100 \cdot (k_{1a}+k_{1p})/k_2$, and the mean transit time MTT as $1/k_2$. Statistical significance and odds ratios (O.R.) were computed using a logistic regression analysis.

Parameter	Regress. P-value	O.R. (95%CI) low	O.R. (95%CI) high	Controls	Cirrhosis
F_a (ml/100g/min)	0.04	1.01	1.16	8.7	33.0
F_p (ml/100g/min)	0.02	0.95	0.99	134.0	50.3
MTT (sec)	0.02	1.06	2.10	12.1	33.0
A (%)	0.02	1.02	1.23	6.5	42.1
D (%)	NS	-	-	27.4	38.9

Results and Conclusions

Perfusion parameters F_p, MTT, and A (each separately and all combined) allowed 90.5% accuracy, 89% sensitivity, and 92% specificity in discriminating normal from cirrhotic liver. Cirrhosis was associated with an increased arterial flow rate, decreased portal and total flows, and longer MTT. Whole-liver MR perfusion parameters can effectively detect and potentially evaluate the disease severity in cirrhotic patients.

References

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2. Materne R et al. Assessment of hepatic perfusion parameters with dynamic MRI. Magn Reson Med 2002; 47: 135-42.