T1-weighted DCE MRI with Gd-EOB-DTPA as a Liver Function Test: A Comparison of Two Methods for Deconvolutional Analysis

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Introduction

Scintigraphic methods, currently the only choice for imaging based liver function testing, are hampered by the limited spatial resolution and anatomic detail of the images obtained. Regional differences in hepatocyte function may therefore be hard or impossible to detect. Using scintigraphy with ^{99m}Tc-IDA, Brown et al described a method to calculate Hepatic Extraction Fraction (HEF) as a marker of hepatocyte function[1], using Fourier transforms with an appended tail for deconvolutional analysis (DA). The pharmacodynamic properties of Gd-EOB-DTPA are similar to those of the ^{99m}Tc-IDA-family with hepatocellular uptake and subsequent biliary excretion[2]. Thus, hepatic uptake of Gd-EOB-DTPA and subsequent T_1-relaxation shortening are dependent on the integrity of the hepatocyte mass. Dynamic Gd-EOB-DTPA MRI has previously been used in animal models to evaluate hepatic function, either using summary parameters or DA[3,4]. In MRI brain perfusion studies[5], matrix inversion using singular value decomposition (SVD), is commonly used for DA. The aim of this study was to assess the feasibility to calculate HEF as a marker of hepatocyte function on a segmental level using dynamic Gd-EOB-DTPA-enhanced MRI, and to compare the results using the Fourier method (below called FA+tail) and truncated SVD (below called TSVD) for deconvolution analysis.

Materials and methods

Gd-EOB-DTPA-enhanced MRI was performed on 20 healthy volunteers (10 women and 10 men), age ranging from 22 to 45 years. Informed consent was obtained prior to examination and the study was approved by the Regional Ethical Review Board. Data was collected using a Philips Intera 1.5T scanner (Best, Holland), with a Philips four-channel SENSE body coil. A T_1-weighted 3D spoiled-gradient-echo pulse sequence (Repetition Time/Echo Time/Flip Angle 4.1ms/2.0ms/10deg, Field Of View=415 mm, matrix resolution 256x192, 40 slices, slice thickness 10 mm and SENSE factor R=2) was used. The volume was imaged in a single breath hold at 41 different time points over a time period of 90 minutes. A dose of 0.1ml/kg Gd-EOB-DTPA 0.25 mmol/ml was injected at the start of the fourth acquired volume. A region of interest (ROI) placed in the hilar part of the portal vein defined the input function. Three ROIs were drawn in each liver segment (I to VIII). DA applying TSVD and FA+tail was performed using in-house software written in MATLAB®. HEF and relative blood flow (RBF) were calculated for each ROI. Parametric maps of HEF and RBF were calculated using the same input function, but with each hepatic voxel representing a response function.

Results

Summary statistics for the HEF and RBF results with the two methods for DA are shown in Table 1, and are presented graphically in Figure 1a and b. The study yielded 180 paired observations of HEF and RBF. There was no significant difference in the overall median with the two methods regarding HEF or RBF, but results with TSVD showed a smaller SD and a smaller CV, although the difference in SD was not significant. Figure 2 shows parametric maps of HEF and RBF.

Table 1.

(n=20)	HEF: TSVD	HEF: FA+tail		RBF: TSVD	RBF: FA+tail	
Mean	*0.215*	*0.217*		*86.1%*	*85.2%*	
Median	*0.208*	*0.210*	*(p=0.524)[1]*	*86.5%*	*86.1%*	*(p=0.331)[1]*
Min	*0.925*	*0.859*		*58.5%*	*55.6%*	
Max	*0.436*	*0.440*		*100%*	*100%*	
Range	*0.343*	*0.354*		*41.5%*	*44.0%*	
SD	*0.0508*	*0.0548*	*(p=0.152)[2]*	*10.5%*	*10.6%*	*(p=0.458)[2]*
CV[3]	*23.6%*	*25.3%*		*12.2%*	*12.4%*	

1)Wilcoxon matched pairs test 2)Variance ratio test 3)Coefficient of Variation
The mean ROI size was 31.9 (SD 21.6) voxels

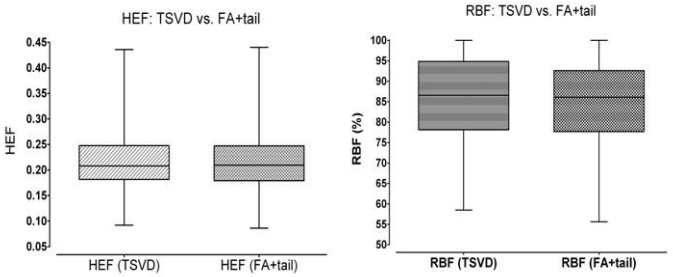

Figure 1a (left) and 1b (right): HEF and RBF results with the two methods of DA

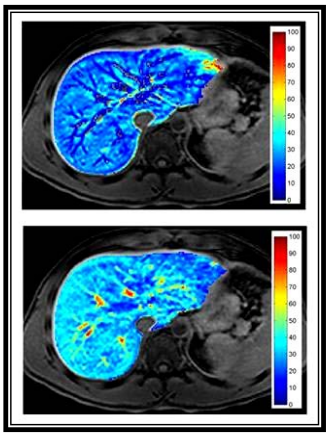

Figure 2: Parametric map of HEF (above) and RBF (below) using TSVD for DA

Discussion

Both TSVD and FA+tail can be used for DA in T_1-weighted DCE-MRI to assess HEF and RBF and the results obtained are similar. TSVD behaves marginally better than FA+tail for DA in vivo, but the difference in SD did not reach significance in our study. A concern is the range of HEF and RBF values that was observed. The variation is probably in part explained by motion artefacts over the acquisition period of 90 minutes. This in combination with partial volume effects of the ROIs leads to noisy data with voxels not necessarily reflecting liver parenchyma in the full dynamic volume. Motion artefacts in high resolution liver function tests like the one we propose probably has to be dealt with to increase data quality. In conclusion, we believe that the pharmacodynamic properties of Gd-EOB-DTPA, in combination with the high resolution obtained in MRI images, opens up the possibility to use DCE MRI with Gd-EOB-DTPA as an imaging based liver function test, with the possibility to discriminate difference in function on a regional or even segmental level. To our knowledge, this has not been studied in humans before.

References

1. Brown PH, Juni JE, Lieberman DA, Krishnamurthy GT. Hepatocyte versus biliary disease: a distinction by deconvolutional analysis of technetium-99m IDA time-activity curves. J Nucl Med 1988;29(5):623-630.
2. Schmitz SA, Muhler A, Wagner S, Wolf KJ. Functional hepatobiliary imaging with gadolinium-EOB-DTPA. A comparison of magnetic resonance imaging and 153gadolinium-EOB-DTPA scintigraphy in rats. Invest Radiol 1996;31(3):154-160.
3. Ryeom HK, Kim SH, Kim JY, et al. Quantitative evaluation of liver function with MRI Using Gd-EOB-DTPA. Korean J Radiol 2004;5(4):231-239.
4. Shimizu J, Dono K, Gotoh M, et al. Evaluation of regional liver function by gadolinium-EOB-DTPA-enhanced MR imaging. Dig Dis Sci 1999;44(7):1330-1337.
5. Ostergaard L. Principles of cerebral perfusion imaging by bolus tracking. J Magn Reson Imaging 2005;22(6):710-717.