DCE-MRI of hepatocellular carcinoma: perfusion quantification with Tofts model vs. shutter-speed model. Initial experience.

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Target Audience Radiologists and physicists/scientists interested in perfusion quantification.

Introduction DCE-MRI can be used to quantify liver tumor perfusion parameters with the use of pharmacokinetic (PK) models [1], such as the Tofts Model (TM). However, the TM assumes infinitely fast equilibrium inter-compartmental water exchange kinetics, which might not hold true when there is significant contrast agent (CA) extravasation during CA bolus passage through the tissue of interest. The Shutter-Speed model (SSM) [2] takes into consideration the finite water exchange kinetics and the two-compartment SSM version introduces a parameter in addition to the K^{trans} and v_e parameters, the mean intracellular water molecule lifetime, τ_i, to account for the transcytolemmal exchange. In this study, the TM and the SSM are applied to estimate perfusion parameters of liver parenchyma and hepatocellular carcinoma (HCC).

Methods In this ongoing prospective IRB approved study, 9 initial cirrhotic patients with 12 HCC lesions (mean size 6.4 cm, range 1-13 cm) underwent DCE-MRI at 1.5T (Siemens Aera) and/or 3T (Siemens Skyra). 5 patients were scanned twice (on different days). DCE-MRI data was acquired using axial 3D-FLASH sequence covering the whole liver (TR/TE/FA 2.69-2.74/0.97-1.09/9.5-11.5°, 192x106-179, slice thickness 4-5 mm, temporal resolution 1.9-2.5s, 100 volumes acquired) before and after injection of 0.05 mmol/kg of Gd-BOPTA (Multihance). ROIs were placed in liver parenchyma, portal vein, abdominal aorta and HCC lesions after image coregistration and mean signal intensity (SI) time-courses were obtained. The portal venous and arterial inputs were added to be considered as single vascular input function for PK modeling. The liver and HCC SI time-course data were analyzed using TM and fast-exchange-regime-allowed version of SSM to extract K^{trans}, v_e, k_{ep} (= K^{trans}/v_e), and τ_i (SSM only). The parameters that were obtained with both models (K^{trans}, v_e, and k_{ep}) were compared using Wilcoxon test. Reproducibility was assessed in the 5 patients that underwent test-retest by computing the coefficient of variation (CV).

	Liver	HCC	p
K_{TM}^{trans}(min^{-1})	0.20 ± 0.14	0.36 ± 0.41	0.09
K_{SSM}^{trans}(min^{-1})	0.24 ± 0.18	0.61 ± 0.68	**0.02**
p	**0.0001**	**0.0002**	
v_e^{TM}	0.07 ± 0.05	0.05 ± 0.05	**0.007**
v_e^{SSM}	0.12 ± 0.08	0.18 ± 0.24	0.78
p	**0.0001**	**0.0002**	
k_{ep}^{TM}(min^{-1})	2.60 ± 0.81	8.14 ± 11.25	**0.03**
k_{ep}^{SSM}(min^{-1})	1.98 ± 0.62	5.64 ± 9.05	0.11
p	**0.0001**	**0.005**	
τ_i (s)	0.15 ± 0.07	0.60 ± 0.69	**0.0001**

Table 1: Mean ± SD values of liver and HCC perfusion parameters estimated in 9 patients with 12 HCCs.

Results Table 1 shows mean ± SD of estimated liver and HCC perfusion parameters K_{TM}^{trans}, v_e^{TM} and k_{ep}^{TM} for TM and K_{SSM}^{trans}, v_e^{SSM}, k_{ep}^{SSM} and τ_i for SSM. There was a wide variation in parameter values among the tumors. Parameters v_e^{TM} and k_{ep}^{TM} and K_{SSM}^{trans} and τ_i showed significant differences between liver parenchyma and HCC. K_{TM}^{trans}, v_e^{TM} and k_{ep}^{TM} were significantly different when compared with their SSM counterparts. Reproducibility of perfusion metrics was better in liver parenchyma compared to HCC for both PK models, while TM demonstrated better reproducibility than SSM (Table 2).

	Liver	HCC
K_{TM}^{trans}	30.1	38.2
K_{SSM}^{trans}	32.3	44.2
v_e^{TM}	20.5	37.7
v_e^{SSM}	24.2	48.7
k_{ep}^{TM}	24.9	52.7
k_{ep}^{SSM}	24.9	62.6
τ_i	17.43	45.5

Table 2: Coefficients of Variation (%) of DCE-MRI parameters obtained with TM and SSM.

Discussion SSM returns greater K^{trans} and v_e values than those from TM as been previously shown in breast [3] and prostate cancer [4], due to the modeling of the finite equilibrium transcytolemmal water exchange kinetics. In addition to differences in perfusion and permeability found between liver parenchyma and HCC, the substantial difference in τ_i detected with SSM analysis may possibly reflect differences in metabolic activity [5] between the two tissues, suggesting potential utility of τ_i for HCC characterization, although there was a wide SD. A larger number of cases will be analyzed, with histopathologic correlation.

Conclusion Initial data shows different perfusion metrics when computed with the TM and the SSM, with differences observed for K_{SSM}^{trans} and τ_i, but not for v_e^{TM} and k_{ep}^{TM} between liver and HCC for the SSM. Reproducibility of the SSM and the TM is limited in HCC, the SSM showing worse reproducibility.

References
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