Estimation of intravoxel incoherent motion (IVIM)-Kurtosis diffusion-weighted imaging and its application in liver

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Introduction: To evaluate the feasibility of using intravoxel incoherent motion (IVIM)-Kurtosis diffusion-weighted imaging for the noninvasive staging of liver fibrosis in patients with chronic liver disease., we have implemented non-linear least squares (LSQ) -based methods. To fit the numerous parameters of the proposed IVIM-Kurtosis model, a one-step fitting approach vs a three-step approach (segmented LSQ) were compared, analyzed and validated on patient data, for which complementary hepatic biomarkers obtained from blood and biopsies were available.

Material and Method: 18 subjects with chronic liver disease whose histology, conventional blood biomarkers results were known were enrolled in this retrospective study. All patients underwent diffusion MRI acquisitions. The diffusion-weighted images were acquired using a 3T GE discovery MR 750 MRI scanner with 12 b-values (0, 10, 20, 40, 60, 80, 100, 200, 300, 400, 600, 800 s.mm-2). The diffusion signals were fitted, voxel by voxel, by LSQ and segmented LSQ for the IVIM-Kurtosis model. Diffusion parameters estimation was performed from squared ROIs in the right liver. The IVIM-Kurtosis model used for the parametric estimation follows the equation (1)

$$\frac{S_i}{S_0} = (1-f)exp(-b\times D + \frac{1}{6}\times b^2\times D^2\times K_{app}) + f.*exp(-b\times D^*) \quad (1)$$

Where S_i represents the signal intensity at a given b value and S_0 represents the signal intensity with no pulsed diffusion gradient. In the segmented LSQ method, the data of $100 \le b \le 400(s/mm2)$ are first used for the estimation of parameter D with a mono-exponential model in equation (2)

$$\frac{S_i}{S_0} = exp(-b\times D)\ (100 \le b \le 400\ s/mm^2) \quad (2)$$

Then f and D^* are calculated with bi-exponential model with $b \le 400$, while keeping D constant.

$$\frac{S_i}{S_0} = (1-f)exp(-b\times D) + f.*exp(-b\times D^*)(b \le 400\ s/mm^2) \quad (3)$$

Finally, the data of $b = 0\ \&\ b \ge 400$ are fitted for the calculation of parameter K_{app}.

Result: Spearman rank correlation coefficient was calculated to evaluate the correlation between diffusion parameters and histology biomarkers. The result showed the stronger negative correlation between D^* and percentage of fibrosis in segmented LSQ method(r=-0.484,p=0.021) than in LSQ(r=-0.276,p=0.134). The K_{app} parameters estimated by segmented LSQ were found to have a tendency to correlate with ASAT (r=0.33,p=0.089) while the K_{app} estimated by LSQ were not(r=0.18, p=0.229) .

Conclusion: D* and Kapp obtained using IVIM-Kurtosis model could be relevant parameters for the monitoring of hepatic disease. Furthermore, based on these preliminary statistical analyses, the segmented LSQ method may provide more sensitive information than LSQ method.

Reference: [1] Kemėšienė, Jūratė, et al. "Advanced diffusion imaging of abdominal organs in different hydration states of the human body: stability of biomarkers." Heliyon 7.1 (2021): e06072.[2] Chevallier, Olivier, et al. "Comparison of tri-exponential decay versus bi-exponential decay and full fitting versus segmented fitting for modeling liver intravoxel incoherent motion diffusion MRI." NMR in Biomedicine 32.11 (2019): e4155.

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