Investigation of Liver Diffusion Kurtosis Imaging and Perfusion Effect

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Introduction: Diffusion weighted imaging (DWI) and Apparent Diffusion Coefficient (ADC) have shown potential for assessment of several liver diseases. The calculation of ADC from DWI data assumes the Gaussian water diffusion. However, in biological tissue, the water diffusion is altered by cell membrane and tissue compartment and its probability distribution function is no longer precisely Gaussian. Diffusion kurtosis imaging (DKI) was proposed to study the deviation of water diffusion from Gaussian distribution [1], and has been applied to study for more precise neural tissue characterization and better detection of brain diseases. In the liver, however, DKI data acquisition becomes more difficult, because DKI requires higher maximum b-value than conventional DWI, and one suffers from shorter T2 relaxation time of liver and respiratory motion to obtain sufficient SNR for analysis. Also, a prior study using IVIM DWI of liver has shown that the signal decay observed with DWI strongly reflects liver perfusion as well [2]. The aims of this study were 1) to investigate how the selection of maximum and minimum b-value affected the liver DKI analysis, and 2) to assess the feasibility of liver DKI in reasonable scan time.

Methods: Respiratory triggered single-shot echo-planner imaging (EPI) DWI scan with twelve b-values (0, 50, 100, 200, 400, 700, 1000, 1250, 1500, 1750, 2000, 2500 s/mm^2) was performed on a healthy volunteer using 3.0T Achieva MR scanner (Philips Healthcare, Best, the Netherlands). Five ROIs were drawn on the liver, and for each ROI, eighteen signal-intensity decay curves according to different combination of b-values were fitted to the diffusion kurtosis model; $\ln[S(b)] = \ln[S(0)] - bD_{app} + \frac{1}{6}b^2D_{app}^2K_{app} + O(b^3)$. To investigate the perfusion effect on the DKI data, these eighteen b-value combinations were divided into three groups by minimum b-value used for curve fitting, group A: min b=0 s/mm^2, group B: min b=50 s/mm^2 and group C: min b=100 s/mm^2 (Table 1). Also, the signal-intensity decay curve between b0 to b1000 of five ROIs were fitted to IVIM bi-exponential model [2]; $S_b/S_0 = (1-f)\exp(-bD) + f\exp(-b(D+D*))$, to get D* and f for assessment of liver perfusion. At the end, by choosing three b-values from twelve b-values, D and K values were calculated with rapid post-processing algorithm proposed by Jensen et al [3].

$$D = \frac{(b_3-b_1)D^{(12)}-(b_2-b_1)D^{(13)}}{b_3-b_2}, \quad K = 6\frac{D^{(12)}-D^{(13)}}{(b_3-b_2)D^2}, \quad \text{with } D^{(ij)} \equiv \frac{\ln[S(b_i)/S(b_j)]}{b_j-b_i}$$

Results and Discussion: D* and f of five ROIs were (D*(μm^2/ms)/f =) 31.53/0.41, 77.02/0.57, 58.41/0.58, 99.4/0.59, 44.89/0.53 respectively. Example of fitting curves from group A, B and C were shown in Fig.1. There were significant differences in D_{app} and K_{app} between group A and B, and between group A and C (P<0.005) regarding all ROIs (Fig.2). These results suggest that fitting using b0 data introduces large error due to perfusion. The mean values of D_{app} and K_{app} from group B and C of all ROIs were 0.875 and 2.264 respectively, and 3/DK became 1514.39. Considering the minimum point of parabola, the upper bound of b-value might be around 1500. There were some K_{app} values which deviate largely from their average (arrows on the Fig.2), and their maximum b-value used for fitting was 1,000 s/mm^2, might be indicating that the maximum b-value of 1,000 s/mm^2 was too small. Three b-values chosen by considering those results gave nearly equal D and K values to D_{app} and K_{app} acquired by fitting using same range of b-values (Table 2).

Conclusion: This study has shown the perfusion effect on the liver DKI, indicating b=0 data should not be used for analysis. Even though the maximum b-value of 1,500 s/mm^2 is smaller than one used in brain, it gave relatively good results in this study, and it would make liver DKI easier to apply clinical cases.

	group A	group B	group C
range of b-values	b0 - 2500	b50 – 2500	b100 – 2500
	b0 – 2000	b50 – 2000	b100 – 2000
	b0 – 1750	b50 – 1750	b100 – 1750
	b0 – 1500	b50 – 1500	b100 – 1500
	b0 – 1250	b50 – 1250	b100 – 1250
	b0 - 1000	b50 – 1000	b100 – 1000

Table 1: Range of b-value used for curve fitting.

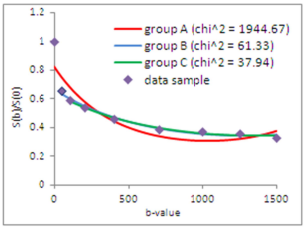

Fig.1: Example of fitting curves from group A, B and C.

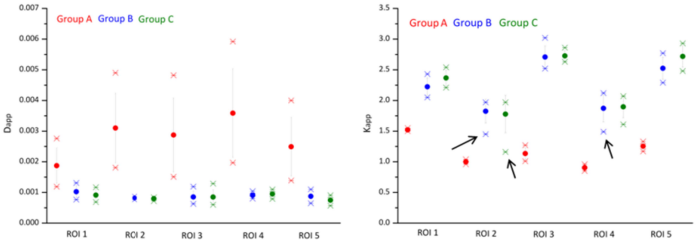

Fig.2: Mean, SD, max and min values of D_{app} (left) and K_{app} (right). Black arrows point min K_{app} value largely deviate from their mean.

	ROI 1		ROI 2		ROI 3		ROI 4		ROI 5	
	D	K	D	K	D	K	D	K	D	K
b50 – 1250 fitting	1.20	2.34	0.85	1.96	0.93	2.79	0.97	1.99	1.03	2.67
b50, 700, 1250	1.20	2.22	1.10	2.16	0.90	2.59	1.10	2.14	1.00	2.54
b50 – 1500 fitting	1.04	2.23	0.86	1.97	0.86	2.70	1.04	2.12	0.90	2.55
b50, 700, 1500	1.10	2.00	1.00	1.99	0.90	2.61	1.10	2.19	0.90	2.31
b100 – 1250 fitting	1.08	2.48	0.84	1.94	0.93	2.79	1.10	2.07	0.83	2.88
b100, 700, 1250	1.10	2.43	1.00	2.20	0.90	2.47	1.10	2.10	0.80	2.96
b100 – 1500 fitting	0.92	2.38	0.84	1.97	0.84	2.73	1.10	2.07	0.77	2.75
b100, 700, 1500	1.00	2.19	1.00	2.04	0.90	2.48	1.10	2.13	0.70	2.67

Table 2: D and K calculated using rapid post-processing algorithm using three b-values, nearly equal to D_{app} and K_{app} acquired by fitting using same range of b-values.

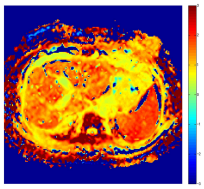

Fig.3: K map calculated using three b-values.

Reference:

[1] Jensen et al., Magn. Reson. in Med. 53: 1432-1440 (2005)

[2] Luciani et al., Radiology 249: 891-899 (2008)

[3] Jensen et al., *Proceedings of the 17th Annual Meeting of ISMRM* Honolulu, 1403 (2006)