Comparing the results of intravoxel incoherent motion diffusion-weighted imaging calculated by different estimation methods

Utaro Motosugi1, Tetsuya Wakayama2, Tomoaki Ichikawa1, Tsutomu Araki1, Suguru Kakite3, and Hadrien Dyvorne3

1Radiology, University of Yamanashi, Japan, 2Advanced Application Center, GE Healthcare, Japan, 3Radiology, Mount Sinai School of Medicine, New York, United States

Purpose: To compare the results of intravoxel incoherent motion (IVIM) diffusion-weighted (DW) imaging model calculated by 5 different estimation methods.

Methods: The liver of a healthy volunteer was scanned to obtain DW images with multiple b values of 0, 15, 30, 45, 60, 75, 90, 105, 120, 135, 150, 175, 200, 400, 600, and 800 s/mm². The scan was repeated 10 times with a few minutes interval. The signal intensities (SI) of each DW image in the right lobe of the liver was used to calculate the IVIM-DWI results using the following equation: \( S_b = S_0 \cdot (1 - f) \cdot \exp(-bD) + f \cdot \exp(-bD^*) \). Where, \( S_b \) = SI on DW image of certain b value; \( D \) = true or slow diffusion coefficient (\( \times 10^{-3} \) mm²/s); \( D^* \) = pseudo- or fast-diffusion coefficient (\( \times 10^{-3} \) mm²/s); and \( f \) = pseudo-diffusion fraction. During the calculation, 5 different estimation methods were used: (A) obtaining the \( D \) value first using DWI of \( b \geq 200 \) s/mm², followed by obtaining \( D^* \) and \( f \) simultaneously using non-linear fitting; (A’) obtaining all 3 values simultaneously using non-linear fitting; (B) obtaining the \( D \) value first as described in method A; (Since the linear regression line suggests the SI contributed by only true diffusion (SItrue), pseudo-diffusion only linear regression line can be drawn using SIpseudo, which were obtained by subtracting SItrue from \( S_b \), and the \( f \) value can be obtained by third linear regression); (C) After obtaining the \( D \) value as described in method A, the \( f \) value was obtained using the intersection of the regression line and SI of \( b = 0 \) (the third linear regression can provide the \( D^* \) value); and (D) Bayesian estimation for \( D \), \( D^* \), and \( f \), which was proposed by Neil JJ and Bretthorst L. Mean values of \( D \), \( D^* \), and \( f \) estimated by the aforementioned methods were compared with each other using the Wilcoxon test with Bonferroni correction. A p value less than 0.005 was considered statistically significant. We also calculated the coefficient of variations (CVs) of each value for the 5 estimation methods.

Results: The results were shown in Box-Whisker plots. The \( D \) values seem to be consistent with no large variability. The CVs of \( D \) values were <10% for all estimation methods. However, the \( D^* \) value by estimation methods B and C, and the \( f \) value by method B had significantly lower results than that obtained by the A, A’, and D methods (p < 0.005). The CVs of \( D^* \) and \( f \) values ranged from 22 to 35% and 8 to 24%, respectively.

Conclusion: IVIM DWI results significantly vary by estimation methods using non-linear and linear regression. Bayesian estimation provides equivalent results of non-linear estimation.