B-value sampling optimization for IVIM diffusion quantification in the liver and kidney at 1.5T and 3T

Hadrien A. Dyvorne[1], Guido H. Jajamovich[1], Niels Oesingmann[2], Thorsten Feiweier[3], Ersin Bayram[4], and Bachir Taouli[1]
[1]*Mount Sinai School of Medicine, New York, NY, United States,* [2]*Siemens Medical Solutions USA, New York, NY, United States,* [3]*Siemens Healthcare, Erlangen, Germany,* [4]*GE Healthcare, Waukesha, WI, United States*

Target audience: M.D. and Ph.D. researchers with interests in abdominal applications of DWI.

Purpose: Intravoxel incoherent motion (IVIM) DWI has recently shown potential to diagnose liver fibrosis or assess kidney function, using parameters that reflect changes in perfusion (PF perfusion fraction and D* pseudo diffusion) or in tissue structure (D true diffusion). For IVIM, a larger number of b values is needed in order to estimate all 3 parameters, which leads to an increase in scan time. The purpose of this study is to reduce the number of b values for IVIM applications in the liver and kidney, using in vivo data acquired with 16 b values.

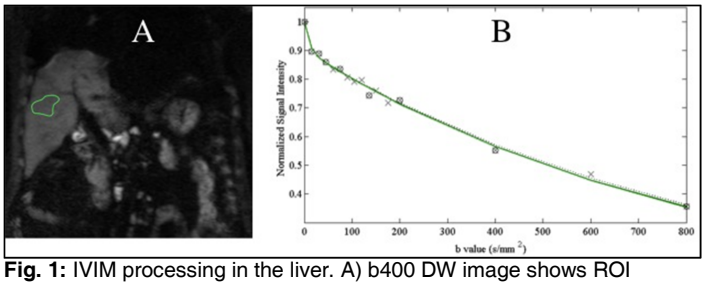

Fig. 1: IVIM processing in the liver. A) b400 DW image shows ROI placement, B) IVIM decay curve in the liver. The solid curve indicates a 16 b values fit (x symbols represent the 16 data points) with D=114x10^{-5} mm^2/s, PF=10.0% and D*=97.6 x 10^{-3} mm^2/s. Using 9 optimized b values (o symbols represent optimized data points) yields almost similar values: D=117x10^{-5} mm^2/s, PF=9.86% and D*=102.0 x 10^{-3} mm^2/s.

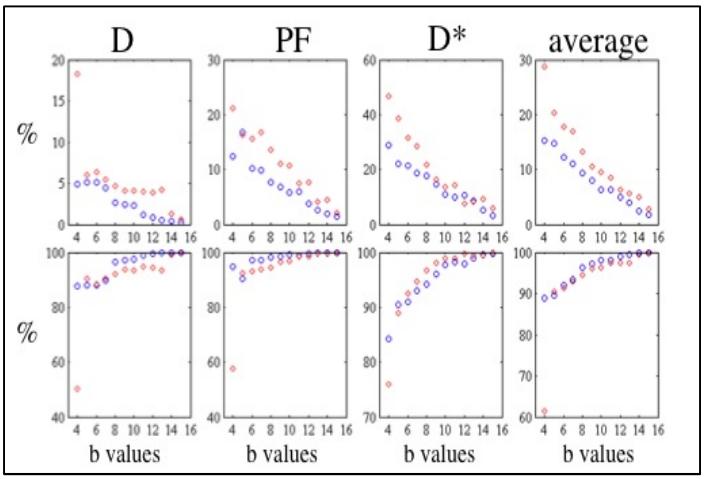

Fig. 2: Evolution of Bland Altman standard deviations (top row) and Pearson correlations (bottom row) between optimized distribution parameters and the reference parameters (obtained with 16 b values) for D, PF and D*, as a function of the number of b values. Blue round symbols indicate 1.5T data, red diamond symbols indicate 3T data. As the number of b values decrease, deviations increase and correlation decrease for all parameters.

Methods: This was an IRB approved prospective study. 56 subjects (M/F 38/18, age 53 ± 12 y) underwent MRI exam at 1.5T (n=28) or 3T (n=28) with SS EPI DWI sampling 16 b values (0 to 800 s/mm^2) at 1.5T (TR/TE 3000/74, resolution 2.3x2.9x8 mm, respiratory triggered, acquisition time 7:55 min) or 3T (TR/TE 3000/52, resolution 3.4x3.4x8 mm, free breathing, acquisition time 3:55 min). ROIs were placed in the right liver lobe and renal parenchyma, and a Bayesian fitting method[1] was used to estimate D, PF and D* from the mean ROI signal intensity decay **(Fig. 1)**. Combinatory b values subsets were drawn from the 16 b values, and the related IVIM parameters were compared with the reference parameters obtained using 16 b values, using Bland Altman comparison and Pearson correlation for each IVIM parameter. For each subset size (4 to 15 b values) the subset achieving lowest parameter deviations in the liver and kidney were elected as optimal distributions.

Results: As the number of b values decreased, the optimized distributions showed increased deviations from reference parameters and decreased correlations with reference parameters **(Fig. 2)**, reflecting a progressive loss in parameter estimation quality. A 9b values distribution (0, 15, 30, 45, 75, 135, 200, 400 and 800 s/mm^2) was found to optimize parameter estimation for both liver and kidney, at 1.5T and 3T. Using this distribution, we achieved deviations lower than 5%, 20% and 30% and correlations higher than 0.92, 0.88 and 0.96 for D, PF and D* respectively.

Discussion: Previous studies have addressed b value sampling optimization in the kidney[2] and pancreas[3], with methods using IVIM decay biexponential model curves disturbed by Gaussian noise. Our study addresses the optimization of b value sampling in the liver and kidney using real in vivo data, and as such is not limited by model assumptions. A 9 b values optimized distribution could be found that provides minimal parameter deviations from a 16 b values distribution in both liver and kidney, at 1.5T and 3T, and decreases the acquisition time by 45%.

Conclusion: Using only 9 b values, it is possible to reduce significantly scan time by 45% from an ad hoc 16 b values distribution with minimal errors in estimated liver and renal IVIM parameters.

References
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