Comparison of Fitting Approaches for Diffusion-weighted MRI Models in Liver Simulation

Jiqing Huang[1], Hélène Ratiney [1], Olivier Beuf[1], Benjamin Leporq[1]

[1]*Univ Lyon, INSA Lyon, CNRS, Inserm, CREATIS UMR 5220, U1206, F-69621, Lyon,*

Goal : To assess the performance of non-linear least squares (LSQ) and Bayesian fitting approaches on various diffusion-weighted MRI models in liver, we simulated multiple b-values diffusion data with varying Rician noise levels according to diverse diffusion methods, including stretched-exponential model (SEM), intravoxel incoherent motion (IVIM), diffusion kurtosis imaging (DKI), and statistical diffusion (StatD) models. Such diffusion models' parameters were estimated by LSQ, Bayesian method with or without initialized by LSQ (Bayesian or LSQ+Bayesian).

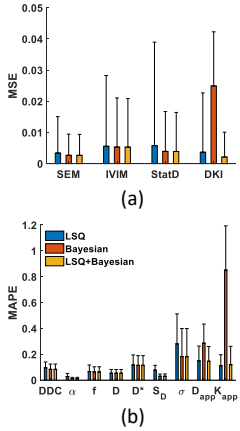

Figure 1 : Estimation results evaluation of signal and parameters, (a) MSE on Signal; (b) MAPE on parameters

Material et Method : In order to keep the intrinsic statistical properties of liver diffusion, b0 (b value=0) images used in our simulation were collected using 1.5T Siemens MRI, and parameter values for each model were obtained from statistical ranges reported in the literature[1-2]. We assume a Gaussian distribution for each parameter. The signals (corresponding to the modalities) with 5 increasing noise deviation (i.e. variance =0,0.0625,0.125,0.25,0.5,1) are calculated according to their diffusion function with up to 13 different b values (i.e. b= {0,10,20,40,80,120, 200,400,600,800,1200,1600,2000}). It can be formulated as $S_i = S_0\, f(p)$ where S_i and S_0 are respectively acquiring signal with b value equal to i and 0, p and f(·) are corresponding models' parameters and function, respectively. After generating signals, multiple parameters were estimated by LSQ, Bayesian, and LSQ+Bayesian.

Results : The estimation's quality was evaluated by mean square error (MSE) for signal and mean absolute percentage error (MAPE) for parameters. Fig.1. showed only the accuracy of estimation for σ=0.25. It can be observed that LSQ+Bayesian works better than LSQ and Bayesian on both signal and parameters as LSQ provides good starting values to speeds convergence. With respect to Bayesian, the average improvement of LSQ+Bayesian on MSE and MAPE is respectively 13.5% and 3.1% (with 13.2% for DKI parameters only).

Conclusion : We have compared performances among LSQ method and Bayesian methods for estimating multiple diffusion models parameters from numerical simulations miming MR diffusion signal in the liver. These numerical experimental results proved that LSQ+ Bayesian performed better compared with LSQ and Bayesian method in all cases. These preliminary results need to be confirmed in vivo.

References : [1] Hu G, et al. Staging of rat liver, Oncotarget. 2018 Jan 5;9(2):2357. [2] Yablonskiy, et al. Statistical model for diffusion, MRM.2003 Oct;50(4):664-9.

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