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Spatially-Constrained Incoherent Motion (SCIM) Model Improves the Robustness of Fast and Slow Diffusion Parameter Estimation from DW-MRI Data in Various Multiple b-Value Acquisition Protocols

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Purpose: Quantitative analysis of Diffusion-weighted MR (DW-MR) images has the potential to provide quantitative and objective insight into tissue physiology and to serve as a biomarker in many clinical applications. For instance, DW-MRI images are used to highlight regions with restricted diffusion such as bowel inflammation in the setting of Crohn's disease (CD)[1,2]. Specifically, the intra-voxel incoherent motion (IVIM) model aims to distinguish between the fast and slow diffusion components of the signal decay[3,4]. However, the high sensitivity of the model parameter estimates to the b-values used in the acquisition using the <u>independent voxel-wise</u> IVIM model have hampered the definition of clinically relevant thresholds for normal and abnormal fast and slow diffusion values across institutions that may use different acquisition protocols. The Spatially-Constrained Incoherent Motion (SCIM) model[5] aims to improve the quality of the fast and slow diffusion parameter estimates by utilizing a spatial homogeneity of the signal decay parameters as an informative prior to guide the estimation, and effectively estimates parametric maps representing the signal decay model using the Fusion Bootstrap Moves (FBM) solver[5]. Here, we aim at evaluation of the SCIM model on improving the robustness of fast and slow diffusion parameter estimates in the ileum against acquisition protocols that utilize different choices of b-values.

Materials and Methods: We acquired DW-MRI data from 24 patients with confirmed Crohn's disease (15 males, 9 females; mean age 14.7 years; range: 5-24 years). We carried out MR free-breathing single-shot echo-planar imaging using a 1.5-T unit (Magnetom Avanto, Siemens) with 8 b-values = 5, 50, 100, 200, 270, 400, 600, 800 s/mm^2. A board-certified radiologist with 1 year of experience in abdominal imaging identified the ileum wall in each image. We then manually encircled the ileum wall to define the region of interest (ROI) (Fig 1). To determine whether the SCIM model improves the robustness of fast and slow diffusion parameter estimates against acquisition protocols that utilize different choices of b-values, compared to the IVIM model, we estimated the parameters at each voxel using the IVIM and SCIM models <u>with 22 different combinations of 5, 6, 7, and 8 b-values</u>. We then calculated the variation (standard deviation) in parameter estimates obtained with the IVIM and SCIM models against different b-value combinations for each voxel in the manually annotated ileal regions for the patients, and compared the variance in the estimates using a two-tailed, paired Student's t-test (p-value ≤0.05). We also calculated the Coefficient of Variation (CV) of the parameter estimates against different b-value combinations.

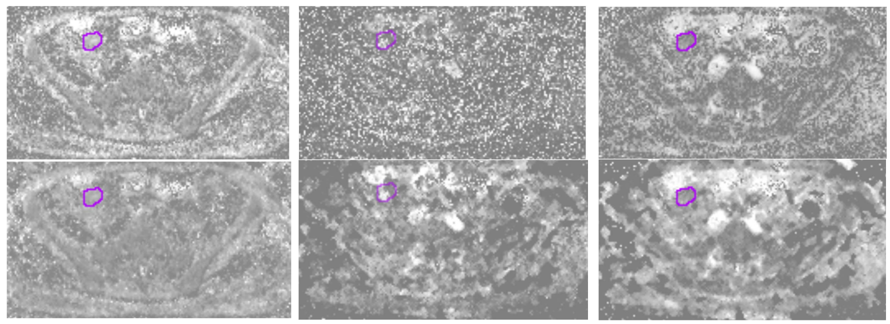

Fig 1: Top row: *D* (left), *D** (middle) and *f* (right) parameter estimation using IVIM; Bottom row: *D* (left), *D** (middle) and *f* (right) *f* parameter estimation using SCIM. The ileum was segmented in purple as ROI.

Results: Table 1 summarizes the variance of the parameter estimates against all combination of b-values for the CD patients. The SCIM model reduced the variance in the parameter estimates compared to the IVIM model. Of note, the reduction in the *D* parameter variance was larger (60%). In summary, the reduction in the variance of the parameter estimates was significant for all diffusion signal decay model parameters in the patients. Figure 1 depicts representative parameter maps generated by the IVIM (top row) and the SCIM (bottom row) models. Figure 2 shows the bar-plots of the CV values for the parameter estimates using different b-values combinations as above mentioned. The SCIM model reduces the CV of the *D*, *D**, and *f* by 26%, 20%, and 28%, respectively, which shows its parameter estimation robustness compared with IVIM.

Table 1: The variation of the incoherent motion parameter estimation over all combination of b-values among the CD patients (mean±std). *D* and *D** are in units of μm^2/ms for the 24 Crohn's disease patients. Significant values in bold

	IVIM	SCIM	p-value
D	1.30±4.93	0.53±0.38	**< 0.00001**
*D**	14.5±9.84	10.5±8.43	**< 0.00001**
f	0.12±0.09	0.11±0.10	**< 0.00001**

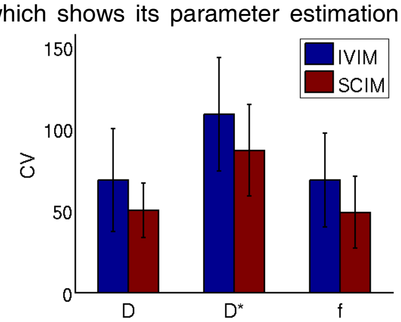

Fig 2: CV of the parameter estimates for 22 combinations of b-values.

Discussion: The use of spatial homogeneity prior substantially improves the robustness of the parameter estimates to acquisition protocols that utilize different choices of b-values. Improving the robustness of fast and slow diffusion parameter estimates against acquisition protocols that utilize different choices of b-values will ultimately pave the way for establishment of fast and slow diffusion threshold values for clinical applications.

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References: **1.** Kiryu, S., et al., J Magn Reson Imaging, 2009. 29(4): p. 880-6. **2.** Oto, A., et al., Journal of Magnetic Resonance Imaging, 2011. 33(3): p. 615-624. **3.** Le Bihan, D., Radiology, 2008. 249(3): p. 748-52. **4.** Le Bihan, D., et al., Radiology, 1988. 168(2): p. 497-505. **5.** Freiman, M., et al., Medical image analysis, 2013. 17(3): p. 325-336.