Robust estimation of IVIM metrics in human liver using Rician noise filter

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Introduction: Introvoxel incoherent imaging (IVIM) has been widely used in characterizing the true water diffusion and micro-perfusion of in various applications [1]. However, estimation of perfusion-related (D*, f) parameters are vulnerable to the Rician noise of diffusion-weighted images (DWIs), especially in cases of liver imaging that features relatively low signal-to-noise ratio (SNR). This study aims to investigate if a Rician nonlocal means (Rician NLmeans) filter may be used to improve the SNR of the IVIM derived parameters while preserving the detailed image information [2].

Methods: Ten healthy volunteers (4 females, 6 males; mean age, 25 ± 4 years old) with no history of liver diseases were recruited in this study and consent forms were obtained prior to the scan.. All volunteers were scanned on a GE 1.5 T whole body scanner equipped with an abdominal phased-array coil. Respiratory-triggered single-shot spinecho EPI DWI was performed with 9 b-values (0, 30, 50, 80, 100, 150, 200, 400, 600 and 800 s/mm^2). The other imaging parameters were: 25 axial slices, TR = 2 respiratory cycles, TE = 69.8 ms, acquisition matrix = 128 × 128. All obtained diffusion weighted images were co-registered to the b_0 image. Registered DWIs and b_0 image were then denoised with an optimized blockwise Rician NLMeans filter [2], and the denoised images were then fitted to the IVIM bi-exponential model $S/S_0 = f\cdot\exp(-b\cdot D^*) + (1-f)\cdot\exp(-b\cdot D)$ and three metrics (true diffusivity D, perfusion-related diffusivity D* and perfusion fraction f) were estimated [1]. In addition, the Chi^2 value was calculated to evaluate the goodness of fit. For comparison, the same IVIM-derived metrics and Chi^2 were also calculated using the images without Rician denosing. For quantitative comparison, the region-of-interest (ROI) was selected along the edge of liver based on the b_0 image. The SNR was then determined by taking the ratio of the mean signal intensity within the ROI to the standard deviation in a homogenous region of liver parenchyma. Statistical comparison of the mean values of SNR, IVIM metrics and Chi^2 with and without RD were performed in SPSS (Chicago, IL, USA). P-values of 0.05 were considered to be significant.

Results and Discussion: Figure 1 shows a representative b0 image and DWI image (b=800 s/mm2) of liver before and after RD. It can be seen that the noise level has been visually reduced by using RD while maintaining the original image details. Statistical analysis showed that the SNR of b0 image and all DWIs increased significantly ($p < 0.01$ for b = 0, 80, 100 and 200 s/mm^2, $p < 0.05$ for the rest b-values) with RD, as shown in Table 1. Figure 2 showed that the mean Chi^2 value dropped from 0.086 to 0.056 when RD was used($p < 0.05$), which indicated improved goodness of fit in IVIM derivation. In addition, the mean D* and f both showed statistically significant decrease from 0.0938 mm^2/s to 0.077 mm^2/s and from 0.397 to 0.350 with $p < 0.05$, respectively. It is interesting to observe that the mean D did not change significantly before and after the use of RD. These results suggest that D* and f are more vulnerable to low SNR than D, and the fitting bias can be greatly reduced by Rician denoising.

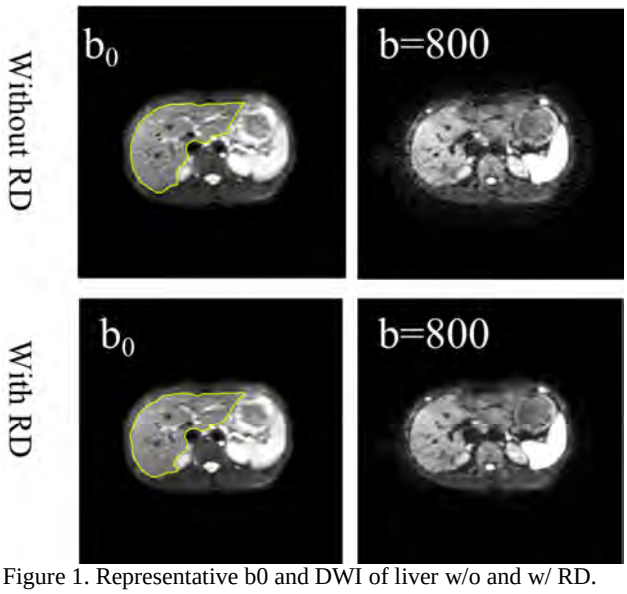

Figure 1. Representative b0 and DWI of liver w/o and w/ RD.

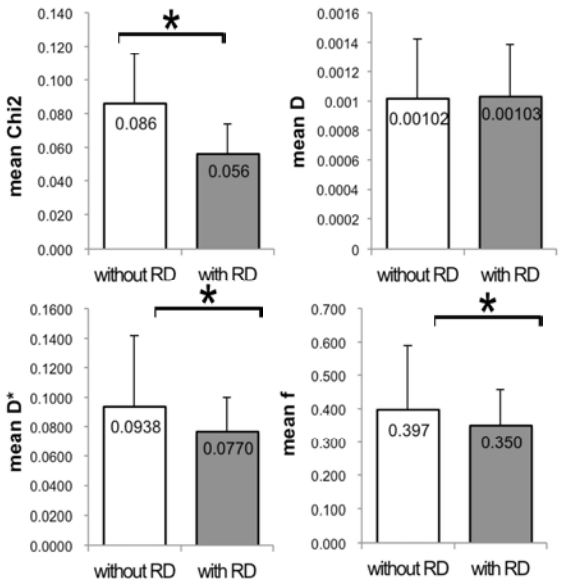

Figure 2. Mean Chi^2, D, D* and f w/o and w/ RD. *:p-value < 0.05

Conclusion: Rician NLMeans filter may efficiently improve the SNR of diffusion weighted images in liver and improve the goodness of fit.

References: [1] Le Bihan et. al., Radiology, 1988. [2] Coupe et al., TMI, 2008.

b-values	0	30	50	80	100	200	400	600	800
w/o RD	18.3	17.4	16.8	15.3	12.3	13.0	8.2	6.8	5.7
w/ RD	21.7	18.9	19.1	21.0	17.4	19.3	10.8	8.7	6.9
P-values	<0.01	<0.05	<0.05	<0.01	<0.01	<0.01	<0.05	<0.05	<0.05

Table 1. SNR of b0 and DWI images before and after RD.