Diffusion behavior in rectal cancer: comparison of mono-exponential, bi-exponential and continuously distributed exponential models

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Introduction: Diffusion weighted imaging (DWI) is increasingly used to evaluate rectal cancer, with the better contrast and sensitivity to delineate tumors as compared to routine T2-W imaging. Quantitation of diffusion usually entails mono-exponential fitting, which does not account for the contribution from intra-voxel incoherent motion (IVIM). A bi-exponential model [1] was proposed which allowed the fast IVIM component to be separated from the slower component to reveal the volume fraction of microvasculature within a voxel and the 'true' molecular diffusion coefficient and showed promising results in human brain and prostate cancer. But it is still unclear whether the bi-exponential model works well in rectal cancer. We proposed the continuously distributed exponential model [2] last year which precluded the assumption about the number of diffusion components. In this study, these three models were compared in fitting accuracy on the rectal cancer diffusion data.

Methods: 14 patients with rectal cancer were enrolled in this study. All the images were performed on a 3.0-T scanner (MR750, GE Healthcare, Milwaukee, WI) with an eight-channel phased-array torso coil. Diffusion-weighted images were acquired in three mutually orthogonal diffusion encoded directions using the following parameters: 16 axial slices, FOV 340 mm, matrix 128 x 128, thickness/gap 5/1.0 mm, TE 69 ms, 12 b-values (NEX): 0(1), 20(1), 50(1), 100(1), 200(1), 400(2), 600(2), 800(2), 1000(4), 1200(4), 1400(6), 1600(8) s/mm2. A respiratory-trigger was employed. The regions of interest (ROI) were drawn on the B0 image with a homogenous area of tumor or normal rectal wall. All the data were fitted by the mono-exponential $S(b)/S(0)=\exp(-b\times ADC)$, the bi-exponential model $S(b)/S(0)=f\exp(-b\times D_{fast})+(1-f)\exp(-b\times D_{slow})$ and the continuously distributed exponential model $S(b)/S(0)=\int A(D)\exp(-b\times D)dD$. The $\chi 2$, calculated from the expression of $\chi^2=\sum(S_{fitted}-S)^2$, was used to evaluate the fitting accuracy of these three different models for all data.

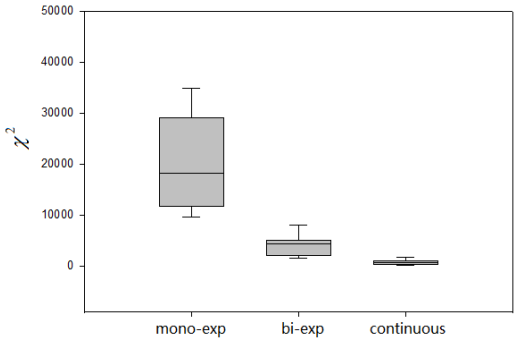

Fig. 1 $\chi 2$ of three models

Results: The results of fitting accuracy are shown in Fig 1. For all the patients data, the χ^2 of mono-exponential model (20130.5±10670.3) is much greater than the bi-exponential model (4225.9±2513.1) and the latter is much greater than the continuous model (701.9±548.0). One typical fitting result is displayed in Fig 2. For this patient, the results of mono-exponential and bi-exponential model were, ADC = 1.6μm^2/ms, Dfast = 6.25μm^2/ms, Dslow = 1.04μm^2/ms, f = 0.33.

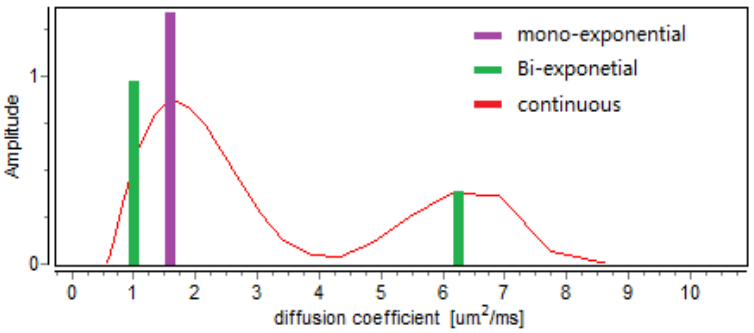

Fig. 2 fitting result comparision

Discussion and conclusion: Based on the preliminary results of this study, the continuously distributed exponential model has an extremely small value of χ^2 in fitting the rectal cancer diffusion data indicating that this model may reveal the 'true' distribution of diffusion components in rectal cancer. In Fig 2, we showed this 'true' distribution of diffusion coefficient (red curve) pattern with two peaks where the left peak has the bigger area. The results of the bi-exponential model (green bar) coincide better with the red curve than the mono-exponential result (purple bar). It implies why the χ^2 of bi-exponential is less than that of mono-exponential. In conclusion, the diffusion behavior of protons in the tissue of rectal cancer could be very complicated. So the continuously distributed exponential model can provide a more accurate result and it could be further used in rectal cancer staging or evaluating treatment response.

Reference: [1] Lee JH, et al., Radiology. 1988;168(2):497-505. [2] Wang H, et al., Proc ISMRM 2011:3892