# Impact of b-value on DTI indices of left ventricular porcine myocardium: a preliminary study


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## Introduction

Diffusion tensor imaging (DTI) has been widely used to characterize myocardium structure nondestructively with high spatial resolution. The conventional DTI assumes that water diffusion is a free Gaussian process and the diffusion weighted signal decays with b-value in a monoexponential manner. However, as the mobility of water molecule varies with different microscopic compartments and components, this assumption may not be applicable in tissues with complex structures such as kidney, neural and breast [1-3]. In this study, impact of b-value on DTI indices of myocardium was assessed and two models for fitting diffusion-weighted imaging (DWI) data were evaluated to test whether water molecules diffuse in a free Gaussian process in left ventricular (LV) myocardium.

## Method

Imaging experiments were conducted on a 3T Siemens Trio MR scanner. Six excised normal porcine hearts were immersed in pure water and imaged with EPI-DTI sequence with six different b values of 0, 500, 750, 1000, 1500 and 2000 s/mm$^2$. The imaging parameters were: TE = 107 ms; TR = 5.3 s; slice thickness = 2.0 mm, slice gap = 0.4 mm; gradient direction = 20; number of slices=15; and NEX=10 with in-plane resolution of 1.23 mm$^2$. The scan time was ~95 min per sample. DTI data was then processed with the software of DtiStudio (Johns Hopkins University; USA) for computation of fractional anisotropy (FA), mean apparent diffusion coefficient (MD), axial diffusivity ($\lambda_{\parallel}$) and radial diffusivity ($\lambda_{\perp}$) pixel by pixel from DWIs with two b values (0 versus 500, 750, 1000, 1500 and 2000 s/mm$^2$, respectively). For each sample, 10 representative slices were selected, from which DTI indices were measured on LV myocardium and averaged among six samples. Monoexponential fitting model $DW(b)/DW(0)=\exp(-bD)$ (Monoexp model) [1, 3] and distribution function based model $DW(b)/DW(0)=\exp(-bD+\sigma^2 b^2/2)$ (Stat model) [3] were performed from all DWIs with six b values using a home-written Matlab program. One-way ANOVA and pos-hoc Bonferroni's multi-comparisons were performed to exam the difference in DTI indices among different b values with $p<0.05$ regarded as statistically significant. Signal-to-noise ratio (SNR) was measured on averaged DWIs along 20 diffusion gradients for each heart sample.

## Results

Values of FA, MD, $\lambda_{\parallel}$ and $\lambda_{\perp}$ computed from five different b values were illustrated in Fig. 1. All the DTI indices gradually decreased with increase of b value. Significant statistical difference exhibited among different b values. DWI data fitting with Monoexp and Stat models was illustrated in Fig. 2. The b-value axis has a logarithmic scale, and the dark dots represent averaged DWI signal intensity measured and averaged from six samples. Clear deviation of the measured DWI values from monoexponential curve was observed, while good fitness was obtained with using Stat model. Table 1 summarizes the fitting goodness with parameters of sum squared error (SSE), $R^2$ and root mean square errors (RMSE). Stat model showed better fitting with smaller SSE and RMSE as well as larger $R^2$ in comparison with Monoexp model. SNR was ~120 for the smallest b-value of 500 s/mm$^2$ and ~89 for the largest b-value of 2000 s/mm$^2$ (not shown).

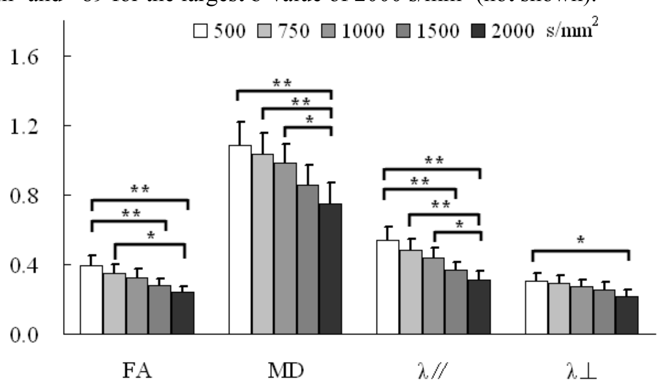


**Fig. 1** Values of DTI indices computed from five b values. $^*p<0.05$, $^{**}p<0.01$, the unit of MD, $\lambda_{\parallel}$ and $\lambda_{\perp}$ is $\times 10^{-3}$ mm$^2$/s.

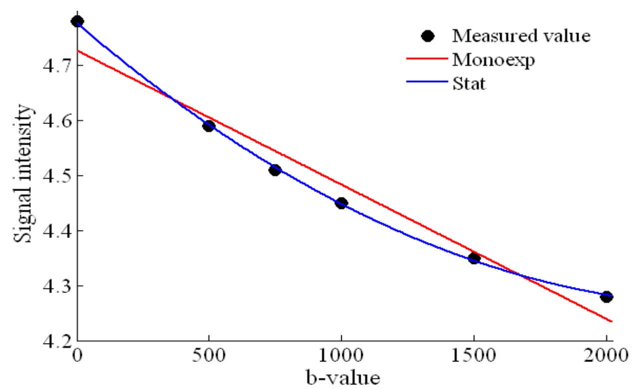


**Fig. 2** Monoexp and Stat model fitting of DWI signals values.

**Table 1** Fitting goodness of two models.

| | SSE | $R^2$ | RMSE |
|---|---|---|---|
| **Monoexp model** | $7.08\times10^{-3}$ | 0.9557 | 0.04207 |
| **Stat model** | $7.39\times10^{-5}$ | 0.9995 | 0.00497 |

## Discussion

In this study, values of FA, MD, $\lambda_{\parallel}$ and $\lambda_{\perp}$ were found to consistently decrease with increase of b-value, and significant difference exhibited among different b values. This may be due to the restricted microstructural compartment [1-3] of LV myocardium. Stat model demonstrated a better fitting for the DWI signals compared to Monoexp model, implying the complexity of myocardium biological structure and the limitation of conventional DTI model in heart study. SNR of all the DWI with different b values was much higher than the minimum requirement, which suggests that the decreased DTI indices with increase of b value is more attributed to the intrinsic microstructural characteristics rather than SNR variations [4]. In summary, this experiment confirmed the conspicuous influence of b-value on DTI indices quantification, and demonstrated the necessity of optimizing b-value and DWI fitting model for better characterizing the myocardium microstructure.

## References


[1] Hui ES et al, NeuroImage, 2010; [2] Peters N et al, JMRI, 2010; [3] Wittsack HJ et al, MRM, 2010; [4] Bastin ME et al, MRI, 1998.