Numerical validation of two-component T2* mapping for cartilages in human knee

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INTRODUCTION

Two-component T_2* mapping on cartilages in the knee has potential to show variations of short-T_2* relaxation which has potential to be sensitive to disruption of collagen fibers (1, 2). As signal-to-noise ratio (SNR) of MR imaging is limited in clinical setting (e.g., SNR ~ 90 at 3T), concerns exist on the performance of two-component T_2* mapping on human, such as the ability to separate two components from a single decay of T_2* relaxation and the accuracy of two-component T_2* fitting. Numerical validation, which provides flexibility in setting up combinations of two T_2* components of interest, was here employed to address these concerns.

METHODS AND EXPERIMENTS

To investigate the separation of two T_2* components from a signal decay, a mono-exponential T_2* decay, $s1(TE)=A*\exp(-TE/T_2*)$, was used to optimally approximate to a bi-exponential T_2* decay, $s2(TE)=a_{21}*\exp(-TE/T_{21})+a_{22}*\exp(-TE/T_{22})$, with $T_{21}<T_{22}$ and $a_{21}+a_{22}=1$. The difference between the two decays, $E=\|s1-s2\|/\|s2\|$, was used to measure the ability of separation. To validate the accuracy of two-component T_2* fitting, a numerical model was created, with a_{21} linearly increasing from 0 to 100 % while a_{22} linearly decreasing from 100 to 0 %. Gaussian noise, $N(0, \sigma^2)$, was added to s2(TE). A customer-developed, NNLS-based, automatic iterative algorithm was employed to perform two-component T_2* fitting to the noisy s2(TE). In the experiments for separation of two components, a_{21} and a_{22} were fixed to (0.5, 0.5) or other values of interest, while T_{21} and T_{22} were increased at a step of 1.0 ms. For the two-component T_2* fitting, a rectangular region of 30×1000 points (wide × long) was used, with a_{21} or a_{22} changing along the width only. Echo time (TE) was chosen at 54 locations between 0.6-70 ms (Fig.1) based on an optimized protocol for knee imaging. SNR=1/σ.

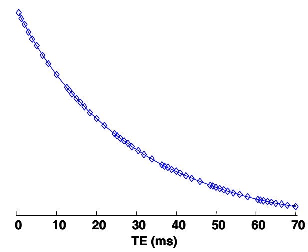

Fig.1. locations of the 54 TEs.

RESULTS AND DISCUSSION

The root mean squared (RMS) error of mono-exponential decay fitting to the bi-exponential at $(a_{21}, a_{22}) = (0.5, 0.5)$ is shown in Figure 2. This error varies with the combination of T_{21} and T_{22}. At the point of $(T_{21}, T_{22}) = (4, 22)$ ms, which represents typical short- and long-T_2* values in cartilages in human knee, the RMS error fell in the yellow-red regions and is larger than 0.8% (Fig. 2). This suggests that short- and long-T_2* relaxations are able to be separated when SNR is appropriate, as shown in Figures 3 & 4. It was also observed that the pattern of the RMS error was changing with the combination of (a_{21}, a_{22}), such as (0.25, 0.75) and (0.75, 0.25), leading to a pattern favorable to T_{22} or T_{21}. The validation of two-component T_2* fitting was shown in Figures 3 & 4. The maps of the fitted a_{21} or a_{22} demonstrated consistency of the fitting across SNR from 90 to 200, 500 and the infinite (Fig. 3), suggesting that fitting for the component intensity fraction (a_{21} or a_{22}) was reliable in clinical setting of SNR=90. The fitted T_{21} or T_{22} value showed a variation with the component fraction a_{21} or a_{22} (Fig. 4); the higher the intensity fraction, the less the variation, and of course, the higher the SNR, the less the variation. At SNR = 90, change of T_{21} (ΔT_{21}) <10% when a_{21}>14%, and ΔT_{22}<10% when a_{22}>20%. These results suggest that, in clinical setting of SNR=90 with 54 TE points, short-T_2* time has an underestimate by less than 10% when intensity fraction is larger than 14%.

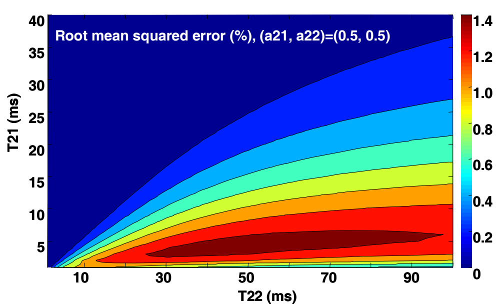

Fig. 2. Error of a mono-exp fitting to bi-exp decay.

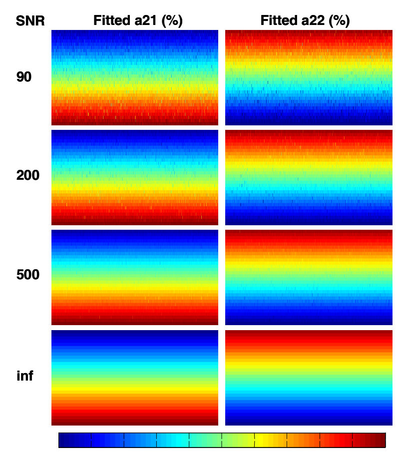

Fig. 3. Maps of the fitted a_{21} and a_{22}.

REFERENCES: [1] Lattanzio PJ, *et al*. MRM 2000; 44:840-851. [2] Qian Y, *et al*. MRM 2012 (Epub, early view).

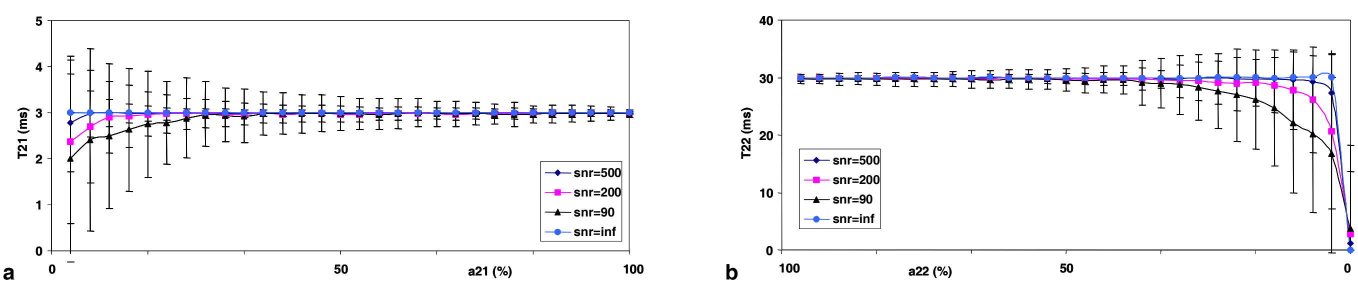

Fig. 4. The fitted value (mean±SD) of (a) short- and (b) long-T_2* time at T_{21}=3ms and T_{22}=30ms, with noise trials of 1,000 at each point.