CHARACTERIZATION OF MULTICOMPARTMENTAL RENAL DIFFUSION USING A STRETCHED EXPONENTIAL MODEL

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Introduction. In biologic tissues, microscopic motion of water not only includes molecular diffusion, but also microcirculation of blood in the capillary network. The intraxovel incoherent motion (IVIM) model has been introduced to describe these combined diffusion and microcirculation effects in diffusion weighted imaging (1). Analysis of the multicompartmental water diffusion is mostly performed by applying a biexponential fit function to the diffusion curve and evaluating the diffusion and perfusion components separately. However, this technique often suffers from high standard fit errors, especially for the perfusion fraction *f*. In 2003, Bennett et al. proposed a stretched exponential model to account for the multiexponential behavior of diffusion curves in the brain (2). This procedure treats the diffusion curve as a continuous distribution and requires no a-priori knowledge about the number of components present. In this work, we extended the stretched exponential model to the abdomen and present fit results from the kidneys of healthy subjects.

Methods. Experiments were performed on a 1.5T system on the abdomen of three healthy volunteers based on 16 axial slices with a matrix of 102 x 128, 2.8 x 2.8 mm^2 in-plane resolution and 6 mm slice thickness. Diffusion curves were acquired using a SPAIR fat suppressed single-shot SE-EPI protocol with 32 *b*-values: 0, 10, 20, 30, 40, 50, 60, 70, 80, 90, 100, 120, 140, 160, 180, 200, 0, 220, 240, 260, 280, 300, 350, 400, 450, 500, 550, 600, 650, 700, 750, 800 s/mm^2, TE/TR = 63/2300 ms, 4 averages, phase partial Fourier 6/8 and GRAPPA parallel imaging with an acceleration factor of 2. Total measurement time was 15 min. Resulting signal amplitudes were fitted using the stretched exponential model described in Equation [1], where *DDC* is the distributed diffusion coefficient and α is a stretching parameter that defines the deviation of the diffusion curve from monoexponential behavior (2). If α is near 1, the attenuation curve will be highly monoexponential. Lower results for α indicate the case of multicompartmental signal behavior. Furthermore, a non-linear least-squares algorithm was used as fit algorithm. Signal amplitudes arising from *b*-value 0 s/mm^2 were excluded from analysis. The following constraints were applied to the fit procedure: $0 < DDC < 10 \cdot 10^{-3}$ mm^2/s and $0 < \alpha < 1$. Renal pixels were segmented using a signal threshold.

$$S(b) = S_0 \cdot \exp\left[-(b \cdot DDC)^{\alpha}\right] \quad [1]$$

Results & Discussion. Figure 1 presents the pixelwise fit results from the kidneys of one healthy volunteer. The fitting procedure was stable and conducted in all renal pixels. Moreover, the resulting maps look smooth and a clear deviation from the monoexponential behavior is observed in the parameter map of *α*. One might as well detect differences in the parameter maps between the cortex and the medulla. Especially in the *α* map, lower values are seen in the cortex than in the medulla indicating a potential higher contribution from the perfusion component in the cortex. Averaged results over all renal pixels and corresponding standard deviations yield 2.14 ± 0.74 $\cdot 10^{-3}$ mm^2/s for *DDC* and 0.77 ± 0.25 for *α*. ROI fit results are illustrated in Figure 2. The incorporation of all 30 *b*-values results in small standard errors < 10 % for both parameters *DDC* and *α*. The reduction to 10 *b*-values yields similar values for the two parameters and slightly increased standard errors that are below 20 % and provides therefore still reliable fit results. The acquisition of only 10 different *b*-values would lead to a possible shortening of measurement time from 15 to ~ 5 minutes making this technique clinically feasible.

Conclusion. We present a new application of the stretched exponential model to the multicomponent analysis of diffusion curves from the abdomen. The stretched exponential model has the advantage of not requiring the exact number of diffusion components in advance. Furthermore, the procedure introduced in this work offers small standard fit errors and as well clinically applicable acquisition times and might therefore provide a real alternative to conventional IVIM imaging and application of biexponential fit equations.

References. 1. Le Bihan et al., *Radiology* **168** (1988) 2. Bennett et al., *MRM* **50** (2003)

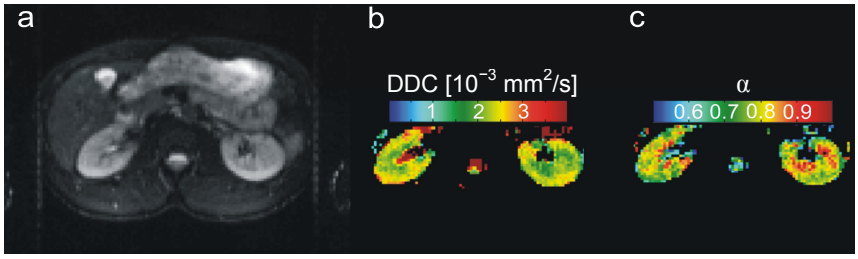

Fig.1: *Pixelwise fit results from one healthy subject.* ***a:*** *b = 0 s/mm^2 image, displayed for anatomical reference.* ***b:*** *Corresponding pixelwise sample image showing DDC parameter fit results.* ***b:*** *Corresponding pixelwise sample image showing parameter fit results for α.*

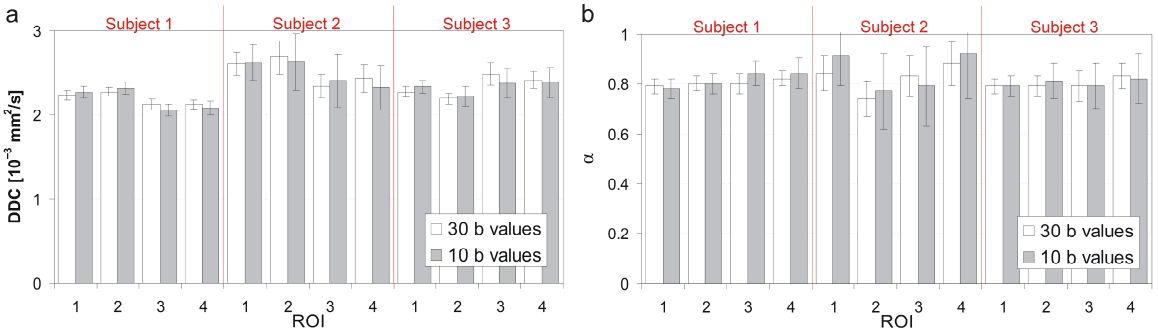

Fig.2: *Fit results of 4 ROIs evaluated in three healthy volunteers showing on the one hand the incorporation of all 30 b-values to the fit and on the other hand the reduction to the 10 following b-values: 10, 40, 70, 100, 160, 220, 280, 400, 550, 700 s/mm^2.* ***a:*** *Fit results for parameter DDC.* ***b:*** *Fit results for parameter α.*