Image co-registration for triggered and non-triggered DTI of the human kidney: Reduced variability of diffusion parameter estimation

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Introduction:

Generally abdominal DTI-scans are performed employing respiratory-triggering to reduce severe physiological motion artifacts caused by respiration. However, even in triggered scans residual motion remains, possibly increasing the variability of diffusion-parameters. This study aimed therefore at investigating the benefit of non-rigid image co-registration of individual echo planar (EP-) DTI-images of human kidneys in respiratory-triggered and also in non-triggered scans.

Methods:

Twenty healthy volunteers were examined on a 3T MR scanner (Siemens, Erlangen Germany). A DW single-shot-echo-planar imaging sequence was applied with ten different b-values (0-700s/mm^2) in 6 non-collinear directions. The first group of 12 subjects was investigated employing respiratory-triggering only, in the second group of 8 subjects DTI was performed in addition without triggering.

Co-registration of individual images was performed using an in-house developed multimodal non-rigid registration software, based on point-wise mutual information [1]. Further data processing included biexponential fitting, yielding ADC and the perfusion fraction F_P (representing microcirculation contributions), and calculation of the fractional anisotropy (FA).

The co-registered and original images were compared in two ways:
1) For each analyzed ROI the standard deviation (SD) was calculated from all pixels within the ROIs;
2) The deviation from diffusion-model fitting was determined comparing the root mean squared error (RMSE). RMSE was determined for fitting the signal only for b-values b<100 sec/mm^2 (RMSE$_{low}$), for b-values b>100sec/mm^2 (RMSE$_{high}$), and for fitting all b-values (RMSE$_{tot}$).

Results:

Visually the co-registered diffusion maps demonstrated less distortions (Fig. 1).

Quantitative analysis of the triggered scans demonstrated: 1) The SDs were significantly lower in co-registered images (Table 1). The mean values of F_P, ADC and FA were also slightly but significantly different, possibly due to lower spurious inclusion of signals from other tissue; 2) All RMSEs were significantly lower in co-registered images (Fig.2).

Analysis of the non-triggered scans also demonstrated lower signal variations after co-registration compared to the original images. However the benefit was less pronounced and the variability compared to the triggered scans (with and without co-registration) was significantly higher.

Discussion:

The results clearly demonstrate the benefit of co-registration of individual EP-images in renal DTI. Although currently the co-registration method does not allow for omitting the respiration-triggering in DTI scans of native kidneys, the lower variation also in non-triggered scans suggests that other organs or transplanted kidneys, where respiration motion is less severe, may be measured without triggering.

References:
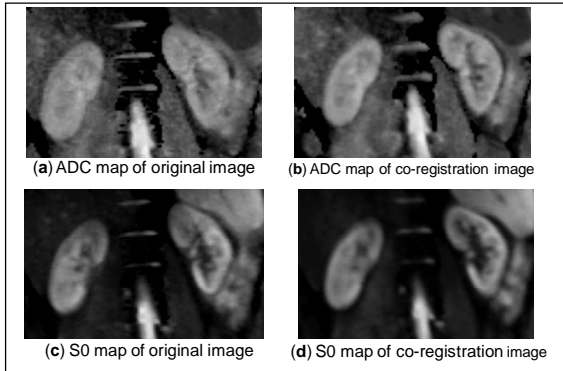
1. Lu H, et al. Conf. Proc. IEEE Eng Med. Biol. Soc. 2010;2010:5951.

Fig. 1: Comparison of ADC and S0 maps from non-triggered DTI scans demonstrated less distortions in Co-registered images.

Fig. 2: Comparison of RMSEs in medulla and cortex between signals from original and co-registered images as a measure for signal variability (triggered scans)

		ADC [10^{-5}mm^2/sec]		F_P [%]		FA	
		mean	SD	mean	SD	mean	SD
medulla	original	194	16	0.15	0.06	0.38	0.09
	co-reg	198	12	0.13	0.05	0.35	0.07
	p-value	>0.1	<0.001	<0.001	<0.001	<0.001	<0.001
cortex	original	203	12	0.17	0.05	0.23	0.06
	co-reg	208	9	0.14	0.04	0.20	0.05
	p-value	<0.01	<0.001	<0.002	<0.002	<0.001	<0.001

Table 1: Comparison of ADC, F_P and FA in kidneys derived from original and co-registered images (triggered scans). SD denotes the mean standar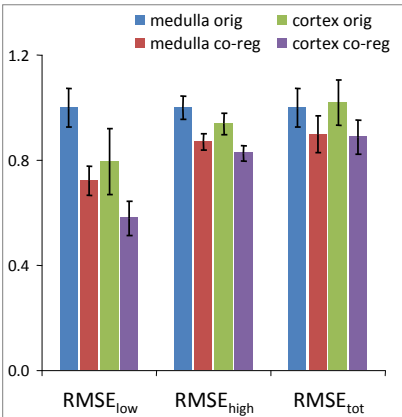d deviation of parameters in ROIs, not between subjects.