IMAGE CO-REGISTRATION FOR RESPIRATORY TRIGGERED AND NON-TRIGGERED DTI OF THE TRANSPLANTED KIDNEY

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Introduction: Recently diffusion tensor imaging (DTI) has gained attention in assessing renal function in healthy and also transplanted kidneys[1-8]. However respiratory motion artifacts reduce the renal image quality in native kidneys and might cause phase misregistration and lead to higher variability of diffusion biomarkers. Therefore, in native kidneys DTI is often acquired either using multiple breath-holds or in performing respiratory triggering at the expense of scan time. Our previous study has shown that performing image registration, based on the method proposed by Lu H. et al.[10], on triggered and non-triggered DTI of native human kidneys reduces significantly motion artifacts and improves signal stability without prolonging scan times[9]. Nevertheless, despite co-registration improvements, the results from triggered scans were still significantly better than those without triggering. Previous diffusion measurements in transplanted kidneys have been performed with and without controlling for respiratory motion [1,6,7]. However, to our knowledge the impact of motion on the results has not been investigated. **Purpose:** The aim of this study was to investigate the impact of the non-rigid image co-registration on DTI of transplanted kidneys and to determine if performing co-registration on non-triggered DTI may allow omitting respiratory triggering for transplanted kidneys.

Methods: Six renal transplants recipients (3 female, 3 male, age=46.0±12.5 y, time between transplantation and MRI from 2 months to 13 years) underwent a DW single shot echo-planar measurement with ten different b-values between 0 and 700 s/mm² in 6 non-collinear directions on a clinical 3T MRI scanner (Siemens Erlangen Germany). DTI parameters were: acq.=2, TR_{min}=3300ms, TE=56ms, a minimal acquisition time of 6 min for non triggered and 12.2±1.2 min for triggered scans. Individual DT images were registered using an in-house image registration software based on point-wise mutual information[10]. One subject was excluded due to polycystic kidney disease. ADC, fractional anisotropy (FA) and perfusion fraction (PF) were calculated using an in-house developed program. Ellipsoid ROIs were manually and independently selected in the upper, middle, and lower pole of the medulla and cortex, on 3 slices with individual ROI sizes of 90±17 and 77±13 pixels for the triggered and non triggered scans, respectively, as well as for the co-registered and the non co-registered images. The co-registered and original images were compared firstly by calculating standard deviations (SD_{ROI}) from all pixels within the ROIs, and secondly by determining the deviation from diffusion-model fitting, i.e. calculating the root mean squared error (RMSE). RMSE was calculated for b-values b<100 sec/mm² ($RMSE_{low}$), for b-values b>100sec/mm² ($RMSE_{high}$), and for fitting all b-values ($RMSE_{tot}$).

Results: The diffusion parameters maps (ADC, FP, FA) did not show visually a considerable difference between triggered and non-triggered scans or with and without co-registration (Fig. 1.). In contrast the quantitative results demonstrated that the SD_{ROI}s of most diffusion parameters were clearly reduced after performing co-registration with some differences reaching significance in both triggered and non-triggered scans (Table 1). Similarly, all RMSEs were lower after co-registration: $RMSE_{tot}$ ($p<0.01$, Fig. 2), $RMSE_{high}$ ($p<0.01$), and $RMSE_{low}$ ($p<0.02$) were significantly lower in medulla after applying co-registration in both, triggered and non-triggered scans. Correspondingly a significant decrease was obtained for $RMSE_{tot}$ ($p<0.01$, Fig. 2), $RMSE_{high}$ ($p<0.01$) and $RMSE_{low}$ ($p<0.05$) in the cortex with triggered scans. The mean values of medullary and cortical ADC, FA, and FP values calculated from co-registered images were similar to those from the corresponding original images in both, triggered and non-triggered scans (Table 1). The diffusion parameters of triggered scans showed no significant difference between medulla and cortex with and without co-registration scheme.

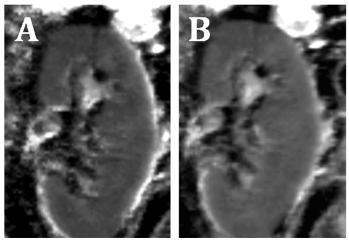

Fig. 1: ADC map of **(A)** Original Non-trig. & (**B**) co-registered Non-trig. renal scans

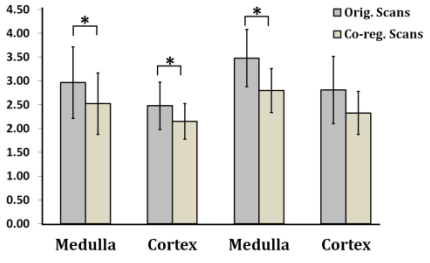

Fig. 2: Comparing relative $RMSE_{tot}$ of medulla and cortex in original and co-registered scans

		Medulla		Cortex	
		ADC [10^{-5} mm²/s]	*SD_{ROI}*	*ADC [10^{-5} mm²/s]*	*SD_{ROI}*
Trig.	*Orig.*	192±10	11.0	200±18	8.9
	Co-reg.	193 ±9	10.5	200±17	8.1
No-Trig.	*Orig.*	191±14	13.4	200±18	9.0
	Co-reg.	192±18	13.6	203±15	7.8

Table 1: Mean ADC and SDs within ROIs of medulla and cortex

Discussion & Conclusion: Co-registration was successfully employed on triggered as well as on non-triggered DTI of transplanted kidneys and the results demonstrated clearly the benefit of performing co-registration by reduced RMSEs in cortex and medulla as well as by reduced standard deviations within ROIs. However RMSEs and SD_{ROI}s were not significantly different between triggered and non-triggered images, which is most likely due to the less respiratory motion sensitive position of the transplanted kidney.

As a secondary finding the corticomedullary ADC and FA differences were smaller than in healthy kidneys which is in agreement with previous results[6]. Mean diffusion values were in the range of previously published values, except for FA, which was slightly lower than reported values [1,6]. This may be due to the small number of subjects in our study, differences in GFR, or the time after transplantation.

In conclusion, the clear improvement due to co-registration and the small difference between triggered and non-triggered images suggest that patients with renal allografts can be measured without respiratory triggering, but employing co-registration to improve the stability.

References: **1. Lanzman RS.** et al. Radiol. 2012; 266(1):218-25, **2. Sigmund EE.** et al. Radiol. 2012; 263:758-69, **3**. **Notohamiprodjo M**. et al. Invest. Radiol. 2008; 43:677-85, **4. Kataoka M**. et al. JMRI 2009; 29:736-44, **5. Cutajar M**, et al. E. J. Radiol. 2011; 80(3):263-8, **6. Thoeny HC**. et al. Radiol. 2006; 241:812-21, **7. Rheinheimer S.** E.J. Radiol. 2012; 81:951-56, **8**. **Vermathen P.** et al. Radiol. 2013; in press. **9. Seif M. et al.** ISMRM 2012, **10. Lu H**, et al. ISBI.2011; 372.