Time-resolved *In Vivo* Cardiac Diffusion Tensor MRI of the Human Heart

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Introduction

Cardiomyocytes form tracts with a crossing helical architecture [1]. The sheer, extension, thickening and radial reorientation of this structure allows the myocardium to contract and relax and function as a pump. Cardiac Diffusion Tensor Imaging (cDTI) provides a non-invasive approach for the depiction of the myocardial fibre architecture [2-8]. *In vivo* cDTI remains extremely challenging due to cardiac and respiratory motion. Several techniques have been used to compensate for cardiac motion and cDTI data have been successfully acquired both at systole and diastole [3,6-9]. The purpose of this work was to perform time-resolved *in vivo* cDTI acquisitions of the healthy human heart over the whole cardiac cycle.

Materials and Methods

The diffusion weighted (DW) STEAM single shot EPI sequence was implemented on a clinical scanner (3T, MAGNETOM Skyra, Siemens AG, Germany) [8]. In order to minimize echo time (TE) and the length of the single shot EPI readout, zonal excitation and partial Fourier (PF) instead of parallel imaging were used. 5 volunteers were scanned. In each session, images were acquired in 7 different phases of the cardiac cycle. Protocol parameters: 6 diffusion encoding directions, b=350s/mm^2, TR=1100ms (for RR intervals=1000ms), TE=15ms, BW=2442Hz/pixel, fat saturation, PF 5/8, spatial resolution=2.7×2.7×8mm^3, 1 slice, 6 averages. Fractional anisotropy (FA), mean diffusivity (MD), helix angle (HA) and superquadric glyph maps [10-11] were created.

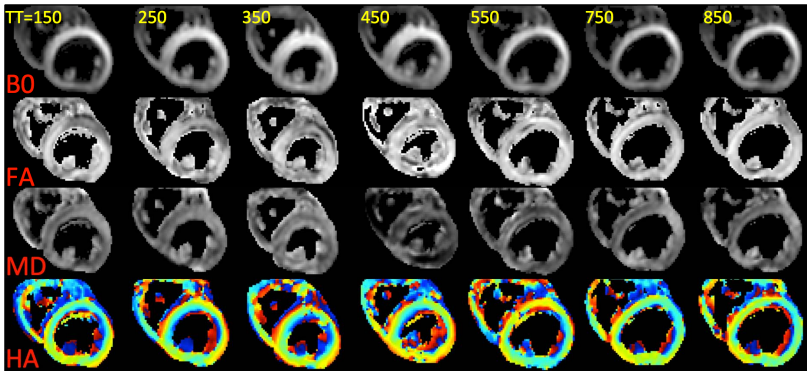

Figure 1. Averaged b0 images, MD, FA and HA maps over 7 different phases of the cardiac cycle. TT= Time to Trigger

Results

Averaged b0 images, MD, FA, HA and superquadric glyph maps over 7 different phases of the cardiac cycle are shown in Figures 1 and 2. The variation in orientation of the diffusion tensor over the cardiac cycle can be observed.

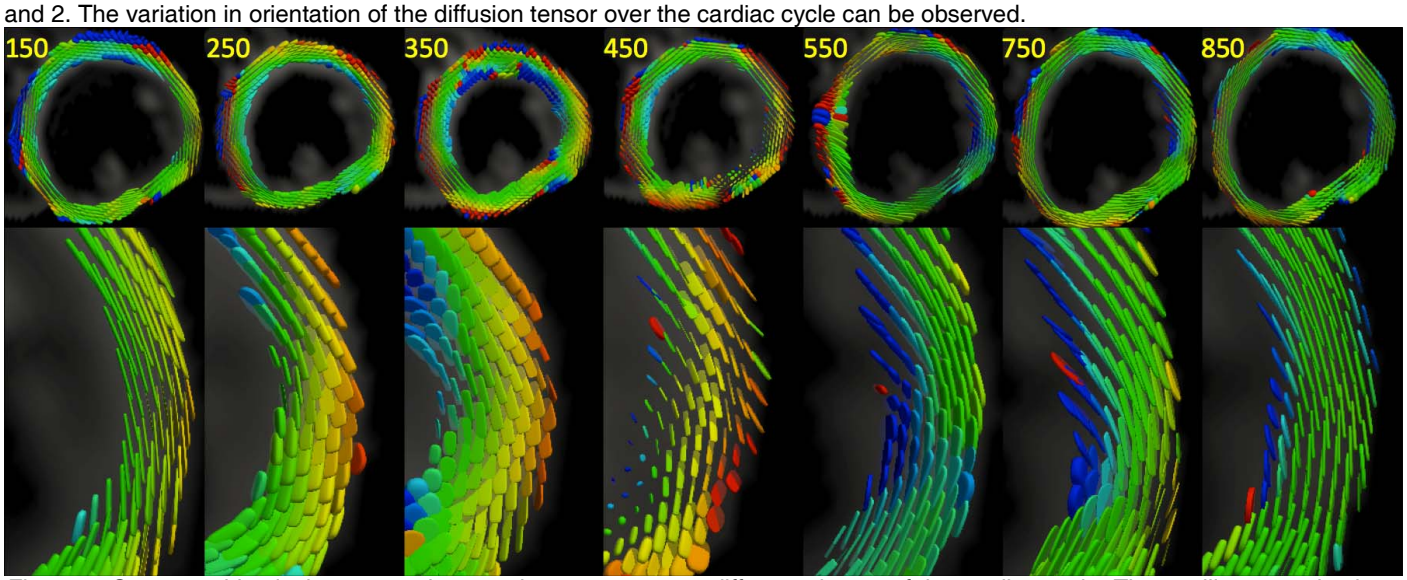

Figure 2. Superquadric glyph maps and respective zooms over 7 different phases of the cardiac cycle. The papillary muscles have been removed from the glyph maps. The rotation of the diffusion tensor as the heart contracts and expands can be observed.

Discussion

The acquisition has been shortened as much as possible to be able to acquire images of the heart at any given point of the cardiac cycle. Nevertheless, since the diffusion encoding uses monopolar diffusion gradients, sensitive to material strains over the cardiac cycle might remain [6,12]. Future work will look into the influence of strain on this data and possible strain correction mechanisms. Quantification of FA, MD and HA changes over the cardiac cycle will follow once a larger number of volunteers has been scanned.

Conclusion

To the author's knowledge, we present for the first time *in vivo* cardiac DTI images distributed over the entire cardiac cycle. The variation in orientation of the diffusion tensor over the cardiac cycle can be observed. The ability to map myocardial fiber structure and its dynamics, especially combined with myocardial strain imaging techniques, could provide novel insights into the structure-function relationships in the heart, and its changes in the presence of disease.

Bibliography

1. Streeter DD. et al. Circ Res 24:339-347(1969) 2. Edelman RR. et al. MRM 32:423-428(1994) 3. Reese TG. et al. MRM 34:786-791(1995) 4. Dou J et al. MRM 50:107-112 (2003) 5. Wu et al. Circulation 114:1036-1045 (2006) 6. Gamper U. et al. MRM 57:331-337(2007) 7. Rapacchi S. et al. Invest Radiol. 46:751-758 (2011) 8. Nielles-Vallespin et al. MRM Sep 21 Epub ahead of print (2012) 9. Mekkaoui C et al. ISMRM 2012. 10. Ennis DB et al. MRM 53:169-176 (2005) 12. Dou J et al. MRM 48:105-114 (2002). 11. Kindlmann G. IEEE TCVG (2004). *This project was funded and supported by the NIHR Biomedical Research Unit at the Royal Brompton and Harefield NHS Foundation Trust and Imperial College London, and the intramural research program of the NHLBI.*