

Temporal Changes in Diffusion Tensor Imaging Parameters in the ex-Vivo Rat Heart

P. W. Hales¹, F. Mason², R. Burton², C. Bollensdorff², P. Kohl², and J. Schneider¹

¹Department of Cardiovascular Medicine, Oxford University, Oxford, Oxon, United Kingdom, ²Department of Physiology, Anatomy and Genetics, Oxford University, Oxford, Oxon, United Kingdom

Introduction

Diffusion Tensor Imaging (DTI) has emerged as a powerful tool for the non-destructive determination of cardiac fibre architecture, providing a valuable source of data for studies into areas such as ventricular mechanics [1] and myocardial remodelling following ischemia [2]. The majority of cardiac DTI experiments are performed on the ex-vivo heart, particularly when high resolution data are required. This is due to the inherent long scan times required to calculate the diffusion tensor, and the high sensitivity of DTI techniques to respiratory and cardiac motion. One area which has received little attention is the possible changes in the DTI derived parameters of an ex-vivo heart over time. This could have a major influence on the 'useable life' of an ex-vivo sample, and, as a typical high resolution 3D DTI scan can take ~60 hours or longer [3], may even effect the accuracy of the DTI data from a single scan. In this study, we repeated diffusion weighted MRI scans of three ex-vivo rat hearts over a 16 day period post excision, to monitor the changes in the ventricular myocardium over a relatively long time period (study 1). Following this, a fourth ex-vivo rat heart was monitored over a 55 hour time period without removal from the magnet, to allow mapping of the temporal changes in the DTI parameters on a voxel-by-voxel basis (study 2).

Materials and Methods

Hearts were excised from Sprague Dowley rats, fixed in Karnovsky's for 12 hours (2% formaldehyde, 2.5% glutaraldehyde mix) and embedded in 1% agarose gel inside a 28mm glass NMR tube. DTI data were acquired using a Varian 9.4 T (400 MHz) MR system (Varian Inc, Palo Alto, CA), comprising of a horizontal magnet (bore size 210 mm), a VNMR5 Direct Drive console, and shielded gradient system (1 T/m, rise time 130 μ s). A birdcage coil with an inner diameter of 28mm (Rapid Biomedical, Wurzburg, Germany) was used to transmit/receive the NMR signals. A diffusion weighted fast spin echo (FSE) pulse sequence, with diffusion gradients applied in 6 non-co-linear directions, was used to acquire 2D multi-slice DTI data in studies 1 and 2, at a resolution of 203 x 203 μ m in plane, slice thickness of 1 mm. During study 2, these scans were interleaved with 3D FSE diffusion weighted scans with a resolution of 406 x 406 x 469 μ m. The diffusion tensor was computed on a voxel-by-voxel basis via a weighted linear least squares fit method, using in house software developed in IDL (ITT Corporation, Colorado, USA).

Results

The change in the total myocardial Fraction Anisotropy (FA) and Apparent Diffusion Coefficient (ADC), averaged over the three hearts in study 1, is shown in Fig.1 (a). These results are normalized to the first time point, and show an average decrease in FA of $16\% \pm 7\%$, and an average increase in ADC of $14\% \pm 11\%$, after 292 hours. By comparison, the mean change in the ADC of the agarose surrounding the three hearts was $-2\% \pm 6\%$ at this point. Fig.1 (b) shows a map of the angle (θ) between the primary eigenvector in the first scan of study 2, and the after the last scan 55 hours later, measured on a voxel-by-voxel basis. The mean value of θ averaged over the entire myocardium was only $1.0^\circ \pm 1.7^\circ$, however this was elevated to $3.1^\circ \pm 1.7^\circ$ in the septal wall region.

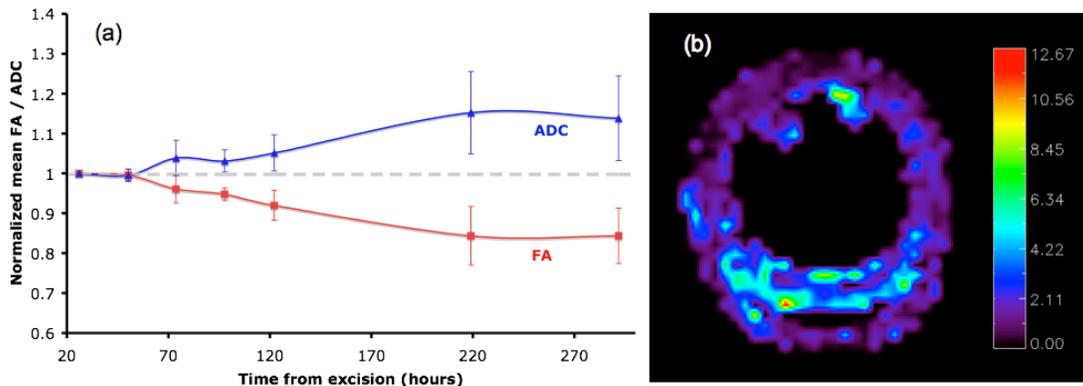


Fig.1 (a) Change in mean myocardial FA and ADC values, averaged over the three hearts in study 1 (normalized to first time point). (b) Mid ventricular short axis slice from the 3D DTI data from study 2, showing angular deviation in the orientation of the primary eigenvector between the first and last time point.

Conclusions

The first part of our study shows that, using the fixation / embedding method described above, the overall mean values of FA and ADC in the myocardium will start to change after approximately 50 hours post excision. This may be due to the decay of myocardium and an influx of water from the surrounding embedding material, which would be consistent with a decrease in FA and increase in ADC. Study 2 has shown that during this 50 hour period, the overall mean change in the primary eigenvector orientation is relatively small, but shows regions of elevated change, which could influence the local model of fibre architecture. Work is in progress to determine whether this is reproducible over a larger number of hearts, and using a variation of protocols for fixation and embedding.

Acknowledgements

This project is supported by the Biotechnology and Biological Science Research Council, grant reference BBE0034431.

References

- [1] Walker JC, Ratcliffe MB, Zhang P, et al. *J Thorac Cardiovasc Surg* 2008;135:1094-1102
- [2] Strijkers, Bouts, Blankesteyn, et al. *NMR in Biomed.* (2008), e-publication ahead of print
- [3] Rohmer D, Sitek A, Gullberg, GT. *Invest. Radio.* 2007; 42(11); 777-84