3T Ex-Vivo High Angular Diffusion Tensor Imaging of the Heart

S. Dymarkowski[1], C. Sage[1], R. Peeters[1], J. D'hooge[2], P. Claus[2], F. Rademakers[2], J. Bogaert[1], S. Sunaert[1]

[1]Radiology, University Hospital of the Catholic University of Leuven, Leuven, Belgium, [2]Cardiology, University Hospital of the Catholic University of Leuven, Leuven, Belgium

Introduction

The ventricular myocardium is known to exhibit a complex spatial organization, with fiber orientation varying as a function of transmural location. It is now well established that diffusion tensor magnetic resonance imaging (DTI) may be used to measure this fiber orientation at high spatial resolution (1, 2).
The purpose of this study was to evaluate the feasibility of high angular DTI in an acquisition time of less than 50 minutes and the feasibility of fiber tracking.

Materials & Methods

One post-mortem pig heart and one sheep heart were casted in a 20% gelatine substance to maintain its shape and subsequently stored at 4°C. Before measurement, the samples were allowed to adjust to a room temperature of 20°C. MR-DTI measurements were performed within 3 days post-mortem. Imaging was performed on a 3T whole body scanner (Intera, Philips, Best, The Netherlands), equipped with a 8 channel phased array human head coil, with the sample positioned centrally in the coil. The DTI sequence was a spin-echo echo-planar-imaging (SE-EPI) DTI sequence with parameters: matrix 64x128, FOV 84x168 mm, 40 slices of 2 mm thickness with a gap of 0.2 mm acquired perpendicular to the short axis of the heart, resulting in a voxel size of 1.31x1.31x2.0 mm, TR= 10607 ms; TE= 68 ms; 32 non-collinear directions with a b-value of 1200 s/mm2; gradient strength of 80 mT/m; SENSE reduction factor = 2; NSA = 8; TA = 48 minutes).
The DTI data sets were transferred to a workstation (Pride, Philips, Best, the Netherlands). After a visual inspection of the DTI images for apparent artefacts, the DTI images were coregistered to remove image distortion that arises from the effect of eddy currents on the EPI readout. Diffusion encoded FA maps were then calculated according to the scheme proposed by Pajevic and Pierpaoli (3). From these FA maps, DTI based color maps were generated, long-axis orientation was encoded as green, short axis LR as red, and short-axis AP as blue. The reconstruction of the fiber tractography was performed by the Fiber Assignment by Continuous Tracking (FACT) method (4,5). A seed ROI was positioned on the middle short-axis slice covering the complete left ventricle.
Image quality (IQ) of the native DTI dataset and calculated FA maps and fiber tractography was rated by 3 observers (0 = non diagnostic, 1 = weak IQ – strong artefacts, 2 = reasonable IQ – little artefacts, 4 = excellent IQ – no artefacts).

Results

Colorized FA maps and fiber tractography of the pig heart can be seen in figure 1. High order shimming significantly improved the image quality in terms of distortions and signal drop outs from susceptibility. Image quality of the native images, FA maps and fiber tractography were graded as 3 (reasonable image quality, slight artefacts) in consensus by the three observers. A parallel imaging (SENSE) infolding artefact was present in the phase encoding direction, due to a to small FOV for the object. The results of the heart from the sheep can be seen in figure 2. In this case additional saturation bands were applied to reduce the SENSE infolding artefact. All observers rated image quality as 4 (excellent, no artefacts). The mean (and SD) FA were 0.386 +/- 0.079, 0.332 +/- 0.114 and 0.398 +/- 0.077 for the mid-wall, endocardial and epicardial muscle tissue respectively.
DTI fiber tractography shows that the mid-wall fibers are mostly oriented concentrically, while epi- and endocardial muscle fiber orientation is mostly diagonal. Finally, a high angular configuration map (fig. 3), reveals that the muscle fibers of the mid-wall cardiac tissue have predominantly a single concentric orientation, while endo- and epicardial muscle fibers have crossing perpendicular diagonal fibres.

Conclusion

Ex-vivo high angular DTI tractography of the heart is feasible in an acquisition time less than 50 minutes. Muscle fibre orientation is consistent with histology.

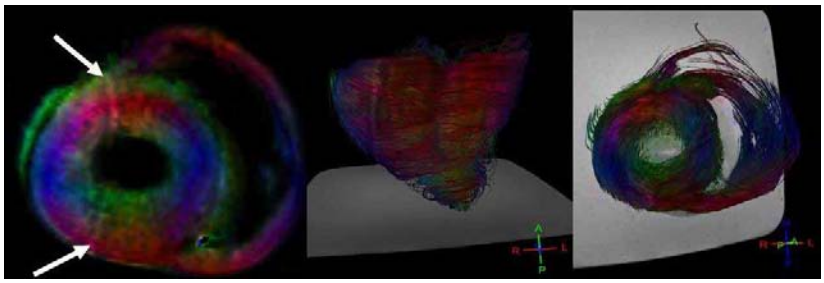

Fig 1. Colorized FA map, and fiber tractography. Arrows indicate SENSE infolding artefact.

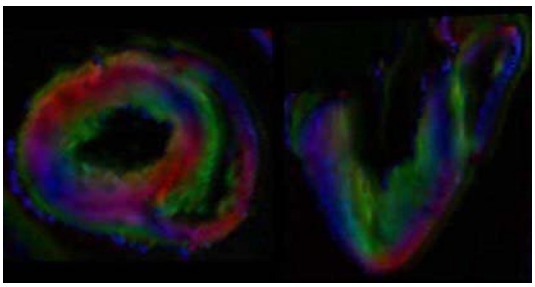

Fig 2. Sheep heart colorized FA images, rated IQ = 4.

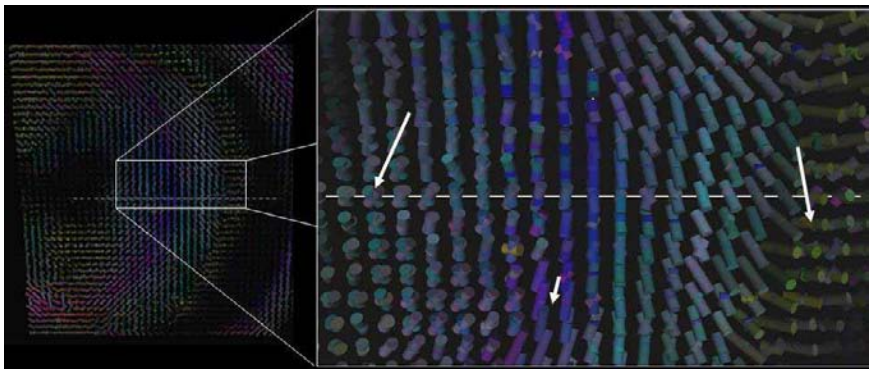

Fig 3. High angular configuration map in a short axis slice. Note the single fiber in the mid-wall muscle tissue (small arrow) and intersecting fibers in the endo- and epicardial muscle (long arrows).

References

(1) Geerts et al. Am J Physiol Heart Circ Physiol 2002: 283: H139–H145
(2) Helm et al. Ann. N.Y. Acad. Sci. 2005: 1047: 296–307
(3) Pajevic S, Pierpaoli C. Magnetic Resonance in Medicine 1999 Sep;42(3):526-40.
(4) Pierpaoli C et al. Radiology 1996 Dec;201(3):637-48.
(5) Basser PJ, Pierpaoli C. Journal of Magnetic Resonance Series B 1996 Jun;111(3):209-19.
(6) Mori S et al. Ann Neurol 1999;45:265-9.
(7) Wakana S et al. Radiology 2004 Jan;230(1):77-87.