COMPARISON OF DIFFUSION TENSOR AND Q-BALL IMAGING OF THE CANINE MYOCARDIUM

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Introduction The myocardial fiber structure is important in determining the anisotropic material and functional properties of the tissue. MR diffusion tensor imaging (DTI) [1] has emerged as a convenient and non-destructive alternative to conventional histology for measuring myocardial fiber orientation [2]. However, DTI is most effective when the imaging voxels contain a single population of parallel fibers whose orientation coincides with the direction of fastest water diffusion. In tissues with multiple, intersecting fiber groups, proper characterization necessitates the use of high angular resolution diffusion imaging (HARDI) such as the so-called Q-ball imaging (QBI) technique [3]. Whereas the existence of crossing fibers is well documented for the brain white matter, little is known of their presence in the myocardium. The goals of the current study are to examine the complexity of tissue fiber structure, and to determine the efficacy of DTI, by comparing diffusion tensor and Q-ball imaging of the myocardium.

Materials and Methods HARDI (0.78 mm in-plane resolution, 5.0 mm slice thickness) was performed in the mid-hemisphere plane of an isolated fixed dog heart using a standard spin echo sequence (TR = 1.0 s, TE = 33 ms, NEX = 6) on a 2.0 T MRI scanner. Diffusion was encoded with b value of 2000 s/mm^2 in 96 independent directions evenly distributed on the surface of a unit sphere. Q-ball orientation distribution function (ODF) (reconstructed along 900 directions) were generated as previously described [3] on a pixel-by-pixel basis. Additionally, diffusion tensors were computed from the identical dataset. The ODF maximum and tensor primary eigenvectors were taken to be the local fiber orientation for QBI and DTI, respectively. Deviation between two fiber orientations was computing via the arccosine of the vector inner product.

Results and Discussions Figure 1 shows the fiber orientation helix angle [4] map obtained by QBI and DTI of the myocardium, respectively, both of which bear the distinctive transmural counter-clockwise rotation of the fiber orientation. Figure 1c shows the difference angle map between fiber orientations obtained by QBI and DTI. The angular difference is small for most of the myocardium, but there exist patches where the difference is conspicuously higher. Over the entire myocardial slice, the mean difference angle is 5.77 ± 0.05° (n = 6400, ±SEM). Figure 2a shows Q-ball ODF renderings (ODF were min-max normalized and rescaled for visualization [3]) for a representative 2 x 2 region with relatively low difference angles. The "peanut-shaped" ODF is indicative of single-fiber populations in the underlying tissue. In contrast, Figure 2b shows regions of high deviation angles have tissues that have complex fiber structure, possibly crossing fibers. Combined, these results indicate that for most of the myocardium the tissue contains single fibers, which can be adequately characterized by DTI. However, there exist local areas, most notably in the insertion points of the right ventricle and roots of the papillary muscle, where the ODF suggests the presence of more complex tissue structure. Although the nature of complex fiber structure needs to be further characterized and validated by, for example, histology, the findings have implications for morphologically-accurate structure-function modeling of the myocardium.

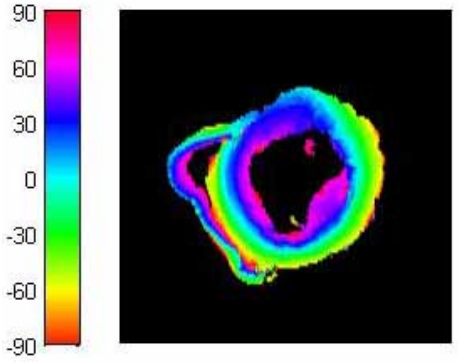

Fig. 1a. Fiber orientation helix angle map in falsecolor obtained from Q-ball ODF.

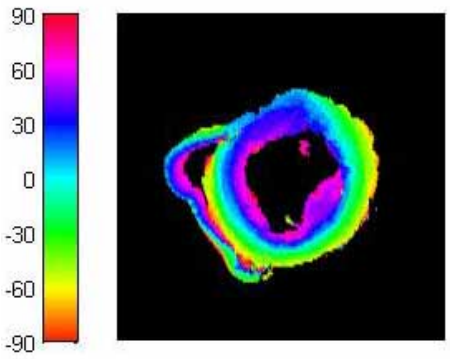

Fig. 1b. Fiber orientation helix angle map in falsecolor obtained from DTI.

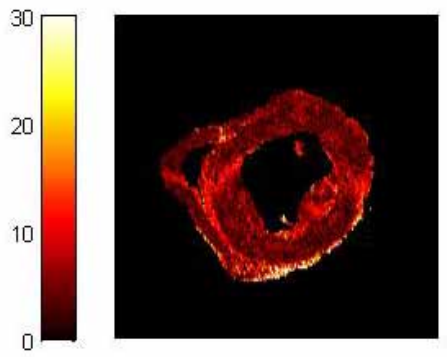

Fig. 1c. Angular difference map of fiber orientations determined by QBI and DTI

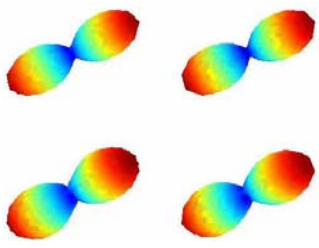

Fig2a Falsecolor ODF from a low angular difference region (anterolateral left ventricle)

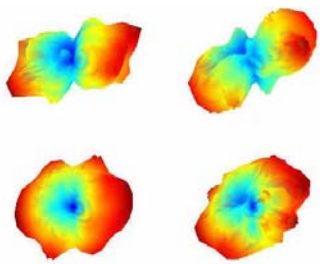

Fig2b Falsecolor ODF from high angular difference region (right ventricular insertion)

References.

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