Diffusion Tensor Imaging of Normal and Ablated Cardiac Left Atrial Specimens

Osama M Abdullah[1], Ashvin K George[2], Nassir F Marrouche[2], and Edward W Hsu[1]
[1]*Department of Bioengineering, University of Utah, Salt Lake City, UT, United States,* [2]*CARMA Center and Division of Cardiology, University of Utah, Salt Lake City, UT, United States*

Introduction The structure of the left atrium (LA) plays an important role in its electrophysiological dynamics, and has been implicated in diseases such as atrial fibrillation (AF). Like other chambers of the heart, a precise knowledge of the 3D microstructure is necessary to better understand and model the structure-function relationships of the tissue. Detailed dissections of the atrial wall transmurally have revealed a complex architecture of overlapping myofibers of different orientations [1-3]. Diffusion tensor imaging (DTI) has emerged as a non-destructive alternative to histology to study highly ordered tissue structures including the myocardium [4], and has so far been applied to characterize the left and right ventricles [4], and right atrial tissue surrounding the sinoatrial node [5]. Because of the differences in the underlying tissue structure, whether the technique is useful for studying the LA is not immediately obvious. The goals of the current study are to determine (a) if DTI is sensitive to the heterogeneous and anisotropic microstructure of the LA, and (b) if DTI can detect alterations of the microstructure following RF ablation procedures, which is commonly used in the treatment of AF [6,7].

Methods Strips of 2-3 cm-wide tissues were excised from the posterior wall of formalin-fixed normal and RF ablated pig left atria obtained from an unrelated study [7]. DTI was conducted on a 7.0 T Bruker Biospec scanner using a 3D diffusion-weighted spin echo sequence (500/22 ms TR/TE, 0.16 mm^3 isotropic resolution, and 1500 s/mm^2 b-value) along 12 optimized gradients directions. Diffusion tensors were estimated as described previously [4], and used in turn to generate eigenvector and fractional anisotropy (FA) maps.

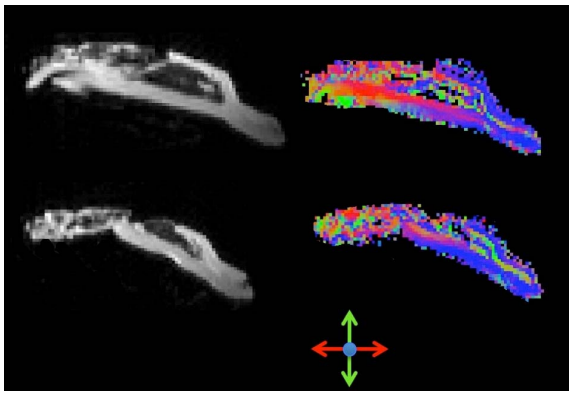

Figure 1. Magnitude images (left) and color-coded myofiber orientation maps (right) obtained in a normal atrial specimen. Two parallel transverse sections are shown.

Results Figure 1 shows corresponding transverse-view MR magnitude images and principal eigenvector (EV1) maps that reveal the general anatomy and fiber orientation observed in a representative normal atrium. The intermixed red and blue regions in the EV1 map indicate that there are layers of myofibers running in perpendicular directions. Figure 2 shows an ablated atrial specimen in circumferential view. The ablated region is characterized by relatively lower FA compared to surrounding tissue. The same tissue with fiber orientations overlaid shows signs of incoherent myofiber in the ablated region.

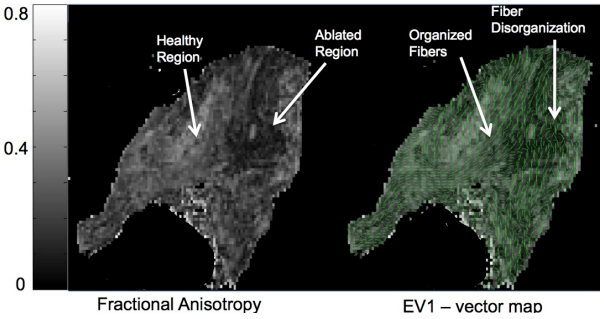

Figure 2. Ablated Specimen FA map (left) with both normal and ablated regions marked by arrows, and EV1 overlay over FA with fiber disorganization clearly shown (right)

Discussion and Conclusion The results clearly demonstrate that DTI can detect and resolve the interleaving myofibers known to exist in the LA from histology [1-3]. Moreover, DTI appear to be sensitive to the structural alterations induced by RF ablation, suggesting that DTI may provide an alternative contrast mechanism to visualize the ablation zone. Combined, these findings are a promising first step to use noninvasive imaging to construct 3D, morphologically-accurate computational models of the normal tissue and tissue under therapeutic intervention.

References [1] Ho SY, Clinical Anatomy 2009;22 :52-63 [2] Papez JW, Am J Anat 1920;27:255–277 [3] Ho SY, J Cardiovasc Electrophysiol 1999;10:1525–1533 [4] Hsu EW et al, Magn Reson Med 2004;52:453-60 [5] Aslanidi OV, Prog Biophys Mol Biol 2011;107(1):156-68 [6] Marrouche NF, Circulation 2003;107:2710-2716 [7] Vergara GR et al, Heart Rhythm Society, 2011;8:295-303.

Acknowledgment The authors thank the CARMA team for providing the atrial specimens.