In-vivo Diffusion Tensor Imaging of the Systemic Right Ventricle at 3T

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Introduction: Recent advances in diffusion acquisition schemes employing stimulated echo modes (STEAM) [1,2,3] now allow for robust diffusion tensor imaging of the beating heart. When used in conjunction with respiratory navigation, data can be acquired during free breathing, making it potentially feasible in patients. In this work in-vivo DTI data were acquired in a patient with a systemic right ventricle, allowing novel insights into the adaptation of myofibre architecture in a morphological right ventricle supporting systemic circulation.

Methods: Scanning was carried out on a 3T Philips Achieva clinical system (Philips Healthcare, Best, The Netherlands) equipped with a 32 channel receive coil array and dual channel transmit coil. Data were acquired using a STEAM acquisition with a single shot EPI readout module [1], at 2mm in-plane resolution and with a slice thickness of 8mm. Fat suppression was carried out using SPIR. Three slices were acquired and the minimum achievable TE was used for all acquisitions (13 ms). Six diffusion directions were sampled [4] with a b-value of 500s/mm^2, and an NSA of 8. A second order image based shimming technique was employed to reduce ΔB_0 inhomogeneities (optimised over the volume of the heart). Using parallel imaging (SENSE = 2.5) and a partial Fourier acquisition (61% coverage) ensured that any remaining ΔB_0 offsets had minimal adverse effect. Respiratory gating was carried out using a 1D navigator placed on the right hemi-diaphragm. The navigator was performed in each R-R cycle using gating windows of 6 mm and 2mm for the STE encoding and decoding parts, respectively. The 2mm gate was applied relative to the respiratory position as detected by the navigator of the encoding part thereby improving gating efficiency relative to implementation described in previous work [3]. Before the scanning session commenced, the patient was trained to perform a prolonged expiration phase for a few seconds for each respiratory cycle. This elongated the gating window and significantly increasing the efficiency. All data were ECG triggered and acquired at end diastole (750ms). Total scan time per slice was ~7 minutes with a navigator gating efficiency of ~30%. Tensors were estimated by solving a linear system of equations based on the log of the diffusion weighted images. The principal eigenvectors of the tensors were extracted. The helix angle (signed angle between the principal eigenvector and the short axis plane) was computed at each voxel.

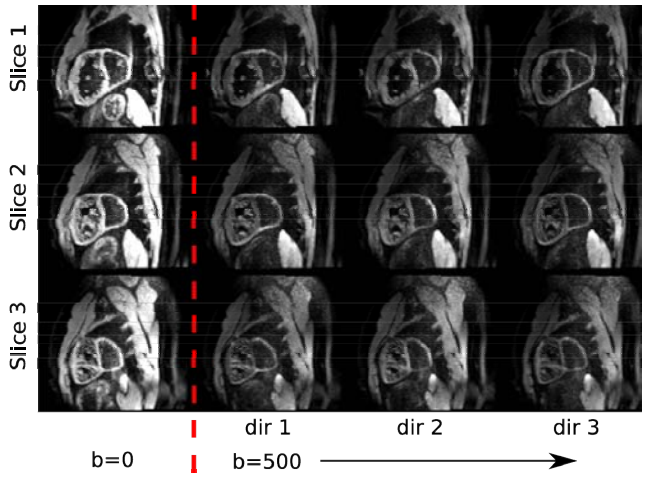

Figure 1: Diffusion acquisition results for all three slices. The b = 0 images along with the first three (of six) diffusion directions (b = 500) are shown.

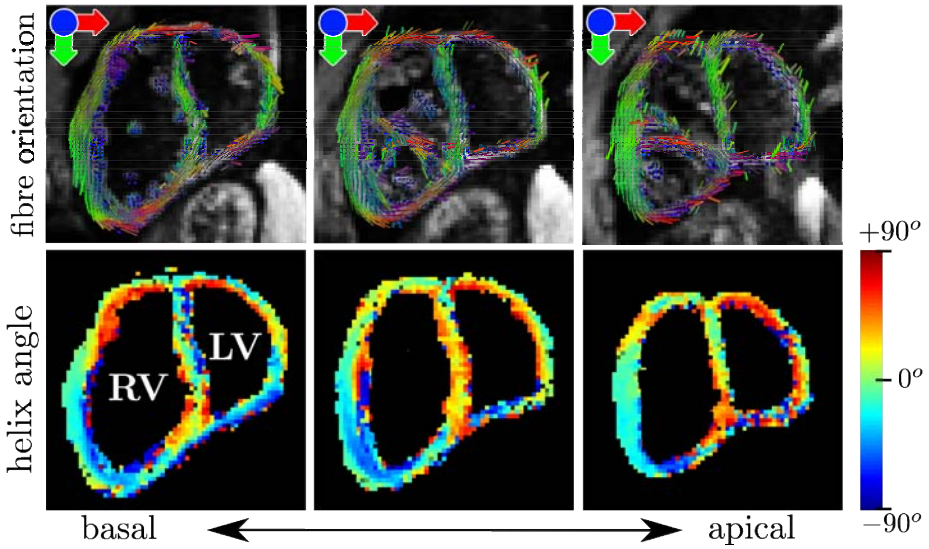

Figure 2: Top: Color-coded DTI slices. The circumferential pattern is clearly visible throughout both ventricles. **Bottom**: Corresponding helix angle maps. Lower angles are observed in the RV.

Results: The diffusion data are presented in **Figure 1**, all three slices are displayed for both the b=0 and b=500 data (first three directions). Resulting maps of principal eigenvectors are shown in **Figure 2** (top). Helix angle maps are presented in **Figure 2** (bottom). A Region Of Interest (ROI) was drawn to segment the right ventricular (RV) wall. The histogram of helix angles from this ROI is presented in **Figure 3**. The same histogram was calculated from a set of 10 healthy left ventricles [5] and is shown in the figure for comparison.

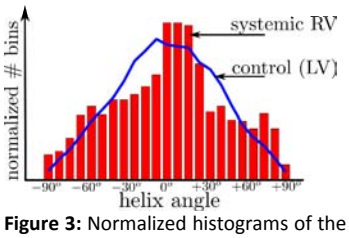

Figure 3: Normalized histograms of the helix angle in healthy LV (blue line, averaged over 10 volunteers), and systemic RV (red bars) from this scan.

Discussion: In previous work, using both tissue Doppler imaging and MRI, it was found that patients with an atrial switch for transposition of the great arteries have a higher circumferential than longitudinal strain in the systemic RV compared to that of the RV of healthy subjects, but similar to that of a healthy LV [6]. A lack of global rotation and obliquely orientated muscle fibres in the systemic RV was reported. These findings may be explained by the flattening of fibres from the epicardium to endocardium in the RV as found in our data **(Figure 2),** given that obliquely angled fibres would normally facilitate the twisting motion of the heart [7]. This characteristic is confirmed in **Figure 3** where we observe a higher peak of helix angles from 0 to 20˚ in the systemic ventricle reflecting a predominance of circumferentially orientated fibres. In summary, this is to our knowledge the first record of in-vivo DTI of a systemic right ventricle. The technique has considerable potential for furthering our understanding of congenital heart disease.

References: [1] Stoeck et al. ISMRM, 2012 [2] Reese et al. MRM, 1995 [3] Nielles-Vallespin et al. MRM, 2012 [4] Jones et al. MRM, 1999 [5] Toussaint et al. ISMRM 2012. [6] Pettersen et al. JACC, 2007 [7] Streeter et al. Circ. Res. 1969.

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