Diffusion tensor MRI (DTI) has been successfully used by several groups to image the microstructure of the heart. A minimum of six non-colinear diffusion encoding gradients are needed to derive the primary, secondary and tertiary eigenvectors/values of the diffusion tensor. These eigenvalues can then be used to derive scalar indices of diffusivity namely, the mean diffusivity (MD) and fractional anisotropy (FA). MD and FA have been extensively used to quantify changes in myocardial microstructure, particularly in ischemic heart disease. Acute infarction is accompanied by a rise in MD and a fall in FA after which the values gradually return towards baseline.

The primary eigenvector of the tensor reflects the average orientation of the myofibers in the voxel. (The secondary eigenvector reflects sheet direction). Orientation in other parts of the body can be described along conventional Cartesian axes. In the heart however, this is of little value, and a separate formulism is required. The scheme followed by most is therefore to describe fiber orientation in terms of the helix angle (HA) the fiber makes with the ventricle. Fibers in the subendocardium have a right-handed or positive HA, those in the epicardium a negative or left handed HA and fibers in the midmyocardium are circumferential. 2D Maps of HA are frequently used as an index of fiber integrity in the myocardium.

Several innovative techniques have been developed to integrate the scalar and vector information provided by the diffusion tensor. These include the use of supraquadric glyphs and super-toroids. The orientation of the glyph or toroid reflects the primary eigenvector, while its shape is determined by the eigenvalues of the tensor. Indices of diffusivity and orthotropy/anisotropy such as the LP ratio, the toroidal volume and the toroidal curvature can be derived from the glyphs and toroids to describe the myocardial microenvironment.

The acquisition of 3D diffusion fields offers the opportunity to integrate the primary eigenvectors into tracts or streamlines. Implementation in the heart has been primarily deterministic using propagation algorithms such as FACT and Runge-Kutta. A termination threshold similar to that used in neurotractography has been used to date, but recent data suggest that this is excessive in normal hearts.

Quantification of the integrated 3D tracts poses a challenge. Fiber HA at the end-points or midpoints of the tract can be used to classify the tract. However, HA is not necessarily uniform along a given tract. We have therefore proposed a statistical approach to 3D myofiber fiber classification. Specifically, we have proposed that 3D myofiber tracts be classified by their median HA. This statistical HA framework also provides a basis to measure 3D tract coherence and reorientation in diseased/remodeled myocardium.

High angular resolution diffusion imaging techniques (HARDI) are being increasingly used in the brain. Examples include q-ball imaging and diffusion spectrum imaging (DSI). Diffusion spectrum MRI involves the use of multiple diffusion encoding or q-vectors to sample diffusion or q-space. The q-space data provide a probability density function (PDF) of fiber orientation in the voxel, which can have many local maxima. Integration of the local maxima in the voxel PDFs into streamlines thus allows multiple fiber populations per voxel to be detected. The need for this degree of angular resolution in the...
heart remains unknown and, while DSI-tractography of the myocardium has been performed ex vivo, its application in vivo would present a formidable challenge. 

References: