ISMRM 2013 – Syllabus

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**Session:** Advanced Diffusion Acquisition: (Sunday Morning 8:00am)

**Talk:** Diffusion MRI in the Heart

Two large themes confront the investigator interested in performing diffusion encoded MRI of the heart. The first pertains to *in vivo* acquisition, which is complicated significantly by cardiac motion.[1] In fact, the motion of the heart is 5 orders of magnitude greater than its diffusion coefficient. Two approaches have thus been developed to overcome this: double-gated diffusion-encoded stimulated echo EPI,[2] and spin echo EPI with motion compensated diffusion encoding gradients.[3] Both approaches involve the use of diffusion tensor MRI (DTI). In the case of the stimulated echo approach, 2 heartbeats are required for a single stimulated echo. The acquisition of 6 diffusion-encoded images plus the B0 image takes 14 heartbeats or a 10-15 second breathold. To achieve adequate SNR, at least 8 breatholds/averages are used per slice. The preliminary experience with these techniques is very promising, and shows that the reproducibility of diffusion-based indices with this approach is high.[4] More recent work, however, suggests that the position of the heart in each breathold varies, and that image registration of the multi-breathold data is needed to improve accuracy.

The second significant issue complicating the use of diffusion-encoded data in the heart is in determining how to represent and quantify the data. Unlike the brain and many other organs, the myocardium is a continuum with no clear end/start points. The most commonly used indices are the mean diffusivity (MD), the fractional anisotropy (FA) and the helix angle [5] (HA), which can be used to assess normal, injured and healing myocardium.[6] More sophisticated approaches have also been developed to represent the entire diffusion eigensystem, including HA, through the use of superquadrics [7] and supertoroids.

The myocardium can also be quantified through considering it as continuous myofiber bundles by integrating the primary eigenvector field into tracts. The first comprehensive application of tractography in the heart involved diffusion-spectrum imaging (DSI) of rat hearts *ex vivo*.[8] While extremely robust, it remains unclear whether the angular resolution of DSI is needed. More recent approaches have involved DTI and have provided equally strong results.[9] Moreover, a statistical classification scheme has been developed to accurately classify myofiber tracts.[9] The integration of sparse DTI datasets has been used to create tracts of normal human volunteers in vivo,[10] but will need further validation. Preliminary data also show that tractograms of a portion of the heart can be created from fully sampled DTI datasets in vivo. However, tractography of the myocardium faces the following issues: What degree of angular resolution is needed in the myocardium? How should myofiber tracts be classified? What are the appropriate termination criteria? Can sparse datasets yield accurate clinical information?

Moving forward, several factors will need to be improved. Currently, it takes ~20 minutes and multiple breatholds in a healthy volunteer to acquire only one fourth of the heart. Patients with heart disease will not be capable of this and will require free breathing navigator based approaches to be developed and validated. Strategies to increase coverage and reduce scan time will also need to be improved. While application of diffusion MRI in clinical care will need to be further demonstrated, these recent advances pave the way towards standardization, broader use and greater utility of diffusion MRI in the heart.

**References:**


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