AbstractID: 11942 Title: Quantitative Cardiac Motion Encoding with Magnetic Resonance Imaging

Quantitative Cardiac Motion Encoding with Magnetic Resonance Imaging

Cardiac magnetic resonance imaging (MRI) is a powerful medical imaging modality that can be safely and effectively used to quantify cardiac structure and function. Imaging the beating heart poses certain challenges that are increasingly met by advances in imaging hardware, image reconstruction, and image processing. In particular, improvements in gradient hardware and coil design have facilitated faster imaging times and real-time cardiac imaging is now routinely possible. Advances in image reconstruction have arisen from the need to robustly reconstruct sparse datasets. The increasing desire for the quantitative evaluation of image data has driven the design of more sophisticated image acquisition and quantitative image processing approaches. This talk will emphasize the latest advances in quantitative cardiac motion encoding with MRI.

The outstanding capabilities of MRI include the ability to clearly contrast different soft tissues, the ability to acquire images of arbitrary orientation, the ability to acquire true three-dimensional image datasets, and the lack of ionizing radiation.

Most of clinical cardiac MRI focuses on the qualitative and semi-quantitative analysis of dynamic scalar (conventional grayscale) images. Scalar images are especially well suited for appreciating gross anatomical structural relationships and global function. In particular, the measurement of right and left ventricular wall masses and volumes, cardiac output, and ejection fraction using steady-state free precession pulse sequences are routinely used to assess cardiac function. With the administration of contrast agents, additional images can be acquired that are informative about regional myocardial perfusion and infarct location and mass.

Remarkably, MRI is not limited to acquiring scalar images. The MRI signal can be sensitized to each velocity vector component for moving structures using a technique termed phase contrast. In this way three-dimensional images of three-dimensional velocity-vector fields can be acquired. In particular, cardiac phase contrast techniques can be used to quantify regional blood flow patterns. This data can be used to quantify trans-valvular flow rates, intraventricular flow patterns and pressure gradients, turbulance, and more. Particle tracing and streamline generation is possible with this kind of data.

Other cardiac motion encoding strategies are implemented for studying regional myocardial wall motion. Such strategies include tagged MRI, harmonic phase (HARP) imaging, and displacement encoding with stimulated echoes (DENSE). Each of these techniques has unique attributes, but each ultimately provides quantitative information about regional myocardial displacement from which regional myocardial strains can be computed. Regional strains are useful engineering measures of myocardial performance. Under these circumstances, MRI can be considered a tensor field imaging method.

Finally, recent research in diffusion tensor MRI (DTMRI) provides a means for the non-destructive evaluation of microstrutural tissue organization in non-moving structures. The requirement for non-moving structures generally limits the application of DTMRI in cardiac imaging to ex vivo tissue samples. The diffusion tensor data contains a wealth of information about the regional vector orientations of the tissue’s myofibers and also more sophisticated measures of tissue anisotropy and the orientation of higher-order structures. The structural organization of the myocardium is essential for understanding myocardial performance. The current goal of many research groups is to integrate the quantitative wall motion, blood flow, and microstructural information into sophisticated finite element models of healthy and diseased hearts.

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Learning Objectives

1) MRI can be used to acquire scalar (conventional grayscale), vector-field, and tensor-field images.
2) Conventional scalar imaging is the clinical norm and is used routinely to observe cardiac structures and quantify global cardiac function.
3) Cardiac MRI can be used to quantify three-dimensional blood velocities. This information can be used to measure flowrates and pressure gradients.
4) Cardiac MRI can be used to quantify regional cardiac wall strains. Regional strains are useful engineering measures of myocardial performance.
5) Ex vivo diffusion tensor MRI can be used to quantify the microstructural organization tissue. The structural organization of the myocardium is essential for understanding myocardial performance.