Evaluation of Cardiac Function - Research Promises

Introduction. Recent advances in rapid image acquisition and reconstruction methods continue to provide important improvements to MRI of cardiac function. New methods for the reconstruction of highly-undersampled raw data, namely compressed sensing (CS) and CS with parallel imaging (CS-PI), are under development and promise to reduce data acquisition times for MRI of cardiac function dramatically (1-4). In particular, these methods promise to accelerate breathhold 2D cine steady-state free precession (SSFP) protocols, and will also improve spatiotemporal resolution in real-time cine MRI. In addition, CS-PI is now being applied to myocardial strain imaging such as cine Displacement-Encoded imaging with Stimulated Echoes (DENSE), providing better spatiotemporal resolution and contributing to new strain imaging applications.

Accelerated MRI. Accelerated cine MRI acquires data that are undersampled in *k-t* space. Using CS or CS-PI, high-quality images can be recovered from data sampled well below the Nyquist rate provided that the sampling pattern is incoherent, the images are sparse in a transform domain, and a sparsity-promoting iterative reconstruction is used. Because of the high temporal and spatial redundancy inherent to cine MRI of the heart, these data can be represented sparsely in a transform domain and are well-suited for acceleration by CS and CS-PI. Due to the non-linear nature of the reconstruction algorithms, these methods can retain high signal-to-noise ratio even as data acquisition times are reduced. CS and CS-PI may be combined with non-Cartesian *k*-space trajectories in synergistic ways, further accelerating data acquisition (5).

Cine MRI. For the general evaluation of cardiac function, 2D breathhold cine SSFP MRI is currently the gold standard method. Using phased-array RF coils and rate-2 accelerated parallel imaging, a typical protocol presently has a spatial resolution of around 1.5 x 1.5 mm^2 and a temporal resolution of around 40 ms, with a data acquisition time of approximately 8 heart beats. With continuing developments in accelerated imaging using CS-PI, future protocols will probably use rate 4 – 6 acceleration and require just 2 - 4 heart beats of data acquisition time. The quality of ungated real-time imaging of cardiac function will also improve using newer methods. For example, Feng et al recently demonstrated the use of rate-8 acceleration to achieve nearly 2 x 2 mm^2 spatial resolution with 40 ms temporal resolution (4), and Uecker demonstrated even higher temporal resolution using an undersampled radial trajectory (5). New techniques may also lead to 3D cine SSFP data sets that can be acquired in a single breathhold. In addition, similar acceleration techniques are effective at reducing scan times for velocity-encoded phase-contrast MRI.

Myocardial strain imaging. To quantify myocardial strain, techniques such as myocardial tagging, harmonic phase imaging, and cine displacement encoding with stimulated echoes (DENSE) continue to undergo technical improvements and continue to be applied to new clinical applications. For example, spiral cine DENSE with CS-PI was recently demonstrated to reduce scan times by a factor of four (6). Also, cine DENSE was recently demonstrated to detect subclinical systolic dysfunction in diabetic patients (7) and in patients with hypertensive heart disease. In addition, cine DENSE was recently shown to be highly effective for detecting cardiac dyssynchrony in heart failure patients and for predicting response to cardiac resynchronization therapy (CRT) (8). In the future, cine DENSE may prove useful in mapping

mechanical activation time (9), potentially providing critical information that may assist cardiac electrophysiologists in optimally placing CRT pacing leads. Overall, strain imaging by MRI continues to undergo substantial technical improvements and new clinical applications of these evolving methods promise to improve the evaluation of heart disease.

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