Complete functional assessment of the mouse heart with one-minute acquisition

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Target audience Researchers working with mouse models of heart disease.

Purpose Heart failure is one of the biggest killers in the Western world. Mouse models of the diseased or abnormal heart can be used as a platform for testing therapeutic agents, but wide variability requires many subjects and characterisation is slow. Screening genetic knockouts for heart dysfunction is time consuming and subjective. In vivo cine MRI is a sensitive, translational technique1 that gives key measures of heart anatomy and function, but with traditional methods it is slow. In past years, acceleration techniques such as parallel imaging and compressed sensing have been successfully applied to accelerate cardiac MRI in the clinic, but these have not seen wide usage in mouse models. Here, we show how the combination of parallel imaging with compressed sensing allows a one-minute acquisition, giving a full functional assessment of the mouse heart with results similar to traditional MRI techniques.

Methods We imaged five normal C57 mice with at 4.7T with a Bruker BioSpec 47/40 system. We acquired sufficient data for full sampling of retrospectively-gated cine MRI of 1mm slices across the heart with Cartesian and radial sampling. For Cartesian acquisitions the scan parameters were: 4.8/1.5 ms TR/TE, matrix 192x192, FOV 3.5x3.5 cm. Radial acquisitions covered 360° with 1440 spokes (256 points per spoke, echo position 5%) with 5.6/1.0 ms TR/TE, FOV 3.5x3.5 cm. To acquire fully-sampled data, both acquisitions were run for 1 minute and 30 seconds per slice. The receiver coil was a four channel array. Navigator signals were combined with principal component analysis (PCA) to extract the cardiac phase and bin the data, and images were reconstructed using a projection over convex sets (POCS) algorithm, including wavelet and temporal Fourier transforms for regularisation and SPIRiT for parallel acceleration2. We tested acceleration factors of 6 and 12 and used the reconstructed images to segment the endocardium and derive functional parameters.

Results The heart rate was 454 ± 30 bpm (mean ± s.d.) during the examination. Using PCA, our self-gating routine extracted the relevant information automatically for both radial and rectilinear MRI. The compressed sensing algorithm successfully reconstructed the cine images without aliasing. The image quality of 6-fold undersampled rectilinear MRI was sufficient to segment the ventricles, while residual aliasing corrupted the measurement on the 12-fold rectilinear undersampling. In contrast, 12-fold accelerated radial images were alias-free throughout the heart. Bland-Altman plots for functional parameters in the radial 12x accelerated case are shown in Figure 2. Good agreement was observed for the undersampled one-minute radial set compared with full sampling.

Conclusions We have shown for the first time that with an accelerated acquisition it is possible to achieve high-quality data with acquisition lasting just one minute. This method is readily applicable for high-throughput drug screening, assessment of genetic phenotypes or longitudinal assessment of recovery following surgical intervention.


Figure 1 Mid-ventricular short-axis slice comparing full sampling, 6x and 12x acceleration for Cartesian and radial sampling.

Figure 2 Bland-Altman plots comparing functional parameters derived from full radial sampling and 12x accelerated radial cine MRI (full-undersampled).