Realtime Cine MRI in Mice with a Single-Shot EPI Sequence and The Karhunen–Loeve Transform

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Background and Aims: Mouse models of cardiac disease play a major role in cardiovascular research but are frequently imaged with echocardiography rather than with MRI. While several groups have shown that MRI can image the mouse heart with an unparalleled level of breadth and detail, many in the cardiac research community remain concerned by the complexity and time-consuming nature of cardiac MRI in mice. Here we present a technique to perform realtime cine MRI in mice with an ungated single-shot echoplanar (EPI) gradient echo sequence. We further show that the quality of the realtime cine images can be significantly improved through the application of a Karhunen–Loeve transform (KLT) filter. The KLT filter is an eigenimage filter that exploits the high degree of temporal correlation in realtime cardiac MR images, and has been shown to boost the SNR of realtime MRI in humans.[1]

Methods: Normal (n=5) and infarcted (n=5) C57Bl/6 mice were imaged on a 9.4T small animal scanner (Biospec, Bruker) equipped with an ultra-high performing 1500 mT/m gradient system (Resonance Research Inc). The mice were imaged supine with a tailored transmit-receive surface coil. Realtime cine MRI was performed in the short axis and 4-chamber views of the heart with a single-shot EPI sequence and the following parameters: FOV 25 x 25 mm, MTX 70 x 64, slice 1mm, TR (temporal resolution) 11ms, TE 3.7 ms, flip angle 22^0 (Gaussian RF pulse 0.4 ms), BW 0.5 mHz, echo position 30%, EPI module duration 9.8 ms, acquisition time 1.1 seconds (100 frames). Application of the KLT filter was performed as previously described in humans.[1] SNR in the myocardium was compared in the unfiltered and filtered images (paired t-test). In the infarcted mice, the extent of hypokinesis on the realtime cine MR images was correlated with the extent of the infarct on delayed (gadolinium) enhancement images.

Results: High quality realtime cines could be obtained in all mice. N/2 ghosting, if present, could be removed in all cases by manual shimming and adjustment of the EPI readout parameters. A high correlation was seen in the infarcted mice between the extent of wall motion abnormalities on the EPI images and the extent of delayed enhancement. The KLT filter significantly improved image quality with SNR in the myocardium increasing from 13.3 +/- 0.9 in the unfiltered images to 20.6 +/- 1.9 in the filtered images ($p < 0.001$). No edge blurring or smoothing was seen in the filtered images. Image quality, and in particular blood-tissue contrast, was significantly higher in the MR images than the tissue contrast obtainable with transthoracic echo. Realtime cine MRI of the entire heart could be performed in less than 5 minutes using minimal sedation, comparing highly favorably with echo.

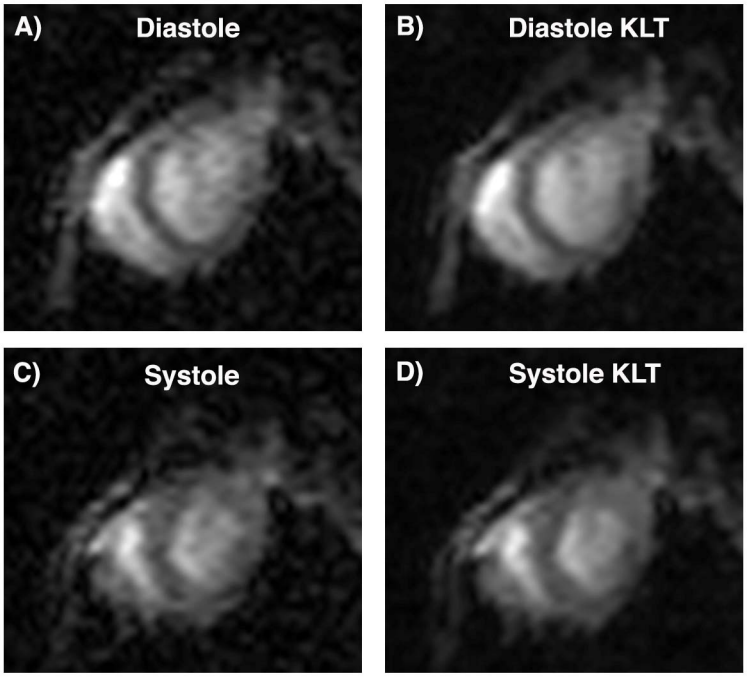

Figure: Diastolic (A) and systolic (C) frames from a realtime cine of an infarcted mouse. (B, D) SNR is significantly higher after filtering with the Karhunen–Loeve transform (KLT). No distortion or edge blurring is produced by the KLT. The lack of systolic thickening in the infarcted lateral wall (compared to the septum) is clearly seen, particularly in the filtered images.

Conclusion: A technique to perform realtime cine MRI of the mouse heart is presented. In addition, the beneficial effect of a Karhunen–Loeve transform filter on realtime MR data is further demonstrated. Realtime MRI in mice offers a high throughput alternative to transthoracic echo and maintains many of the attributes of segmented MR acquisitions. The impending development of parallel acquisition capabilities in mice will significantly improve the spatial and/or temporal resolution of the technique, further increasing its value. Realtime MRI with a Karhunen–Loeve transform filter thus offers a viable alternative to transthoracic echocardiography in both the clinical and basic science research settings, and is an important step towards the more widespread use of cardiac MRI.

References: 1. Ding Y, Chung YC, Raman SV, Simonetti OP. *Phys Med Biol.* 2009;54:3909-3922.

Funding: Supported in part by R01 HL093038 (Sosnovik) and NCRR P41RR14075 (Martinos Center)