Title: Accelerated function: whole heart and real-time

Target audience: Graduate students and research and clinical faculty members interested in applications of compressed sensing (CS) for cardiac cine MRI.

Objectives: Upon completion of this educational presentation, the participants should be better able to:

- Understand the fundamental basis for high acceleration with CS in cardiac cine MRI
- Review different options for k-space undersampling patterns and sparsifying transforms
- Recognize cardiac and respiratory motion as challenges for robust k-t acceleration with CS
- Appreciate the benefits of highly-accelerated cine MRI methods

Purpose: Breath-hold 2D cine MRI with ECG triggering is unquestionably the gold standard for assessment of cardiac function. However, in patients with arrhythmia, breath-hold cine MRI often yields non-diagnostic images in arrhythmia because data acquisition is synchronized to cardiac rhythm and spread over multiple heart beats (i.e., irregular rhythm will cause different segments of cine data to be out of sync and cause image artifacts). For patients in arrhythmia, ungated cardiac cine MRI is diagnostically more useful than ECG-gated breath-hold cine MRI. However, commercially available ungated cardiac cine MRI pulse sequences using parallel imaging typically yield poor spatio-temporal resolution due to their low image acquisition speed. In patients with normal sinus rhythm and breath-hold capacity, it may be desirable to perform highly-accelerated 3D cine MRI with a single breath-hold to speed up the workflow (single breath-hold 3D cine MRI vs. 7 breath-holds for 2D cine MRI). CS (1) or k-t SPARSE-SENSE (2) is well suited to accelerate both real-time cine MRI and 3D cine MRI, because it exploits a high degree of spatio-temporal correlation inherent with k-t data to enforce data sparsity in appropriate domains.

Methods: We developed our accelerated cine MRI pulse sequence with CS using the following steps (Fig. 1). In a numerical simulation experiment (retrospectively undersample a fully sampled data set, perform CS reconstruction, and compare its results with the fully sampled data), we determine the maximum acceleration rate (R) for a given set of k-space undersampling pattern and sparsifying transform. We then perform a prospectively undersampled CS acquisition in vivo and evaluate its image quality and its accuracy and precision for quantification of cardiac function (e.g., LVEF).

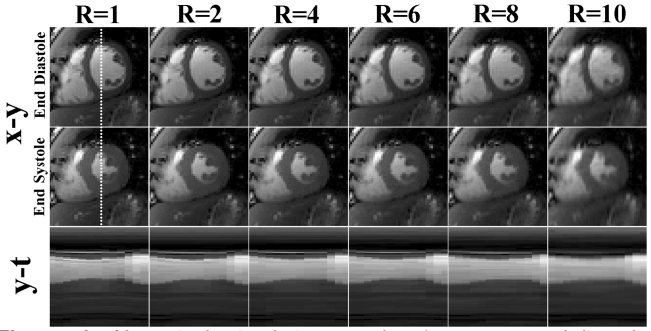

Figure 1. Numerical simulation results (top row: end-diastolic images, middle row: end-systolic images, bottom row: spatial-temporal plots through the blood-myocardium boundary) comparing different R values using temporal TV as the sparsifying transform. These results show good results can be obtained up to R = 8.

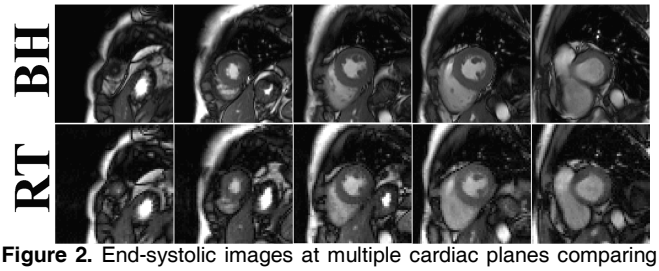

Figure 2. End-systolic images at multiple cardiac planes comparing (row 1) breath-hold cine MRI and (row 2) 8-fold accelerated ungated cine MRI. Note that the breath-hold cine MR images had higher spatial resolution than the non-gated cine MR images (1.6 mm vs. 2.3 mm, respectively).

Results: We have performed an 8-fold accelerated ungated cine MRI with spatial resolution 2.7 mm x 2.7 mm x 8 mm and temporal resolution 43 ms (3). Figure 2 shows representative sets of 8-fold accelerated ungated cine MR images and reference breath-hold cine MR images, in five short axis planes from one healthy subject (in sinus rhythm). Both pulse sequences produced diagnostically acceptable image quality. The resulting LVEF for breath-hold cine and highly-accelerated cine was 56% and 53%, respectively, confirming the accuracy of our proposed 8-fold accelerated ungated cine MR pulse sequence. We have also performed 12-fold accelerated 3D cine MRI with spatial resolution 1.8 mm x 1.8 mm x 6 mm and temporal resolution 45 ms in a breath-hold duration of 22 s (4).

Conclusions: Our 8-fold accelerated ungated cine MRI pulse sequence may be useful for patients with reduced breath-hold capacity, arrhythmia, and/or tachycardia. Highly-accelerated 3D cine MRI is still a work in progress and requires further optimization before it could be utilized in clinical practice.

References Cited: [1] Lustig M, Donoho D, Pauly JM. Magnetic Resonance in Medicine 2007;58(6):1182-1195. **[2]** Otazo R, Kim D, Axel L, Sodickson D. Magnetic Resonance in Medicine 2010;64(3):767-776. **[3]** Feng L, Srichai MB, Lim RP, Harrison A, King W, Adluru G, Dibella EV, Sodickson DK, Otazo R, Kim D. Magnetic Resonance in Medicine. DOI 10.1002/mrm.24440. **[4]** Kim D, Harris A, King W, Feng L, Bassett E, McGann C, Marrouche N, Otazo R. In: Proceedings of the 15th Annual Meeting of ISMRM, Melbourne 2012. p 3837.