Highly Accelerated Cine DENSE MRI with k-t SPARSE SENSE

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Target Audience: Researchers and clinicians interested in quantification of myocardial strain with a rapid MRI method.

Purpose: Quantitative assessment of regional cardiac function can improve the accuracy of detecting wall motion abnormalities beyond qualitative assessment with cine MRI. Displacement encoding with stimulated echoes (DENSE) [1, 2] MRI is a promising method to quantify myocardial strain. While 2-fold accelerated cine DENSE MRI [3] using TSENSE has been validated [4], its breath-hold duration (12 heart beats) may still be too long for critically ill patients. The clinical motivation of this study is to develop highly-accelerated cine DENSE MRI using k-t SPARSE-SENSE [5,6] in order to make the data acquisition feasible in critically ill patients.

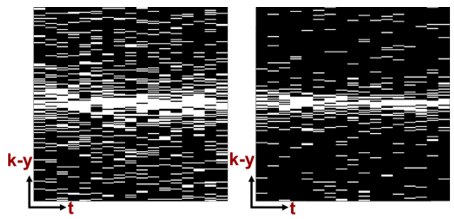

Figure 1: Random ky-t undersampling patterns for acceleration factors (left) R = 4 and (right) R = 8.

Methods: We acquired fully sampled cine DENSE MRI data in two volunteers on a 3T MRI system (Siemens, Tim Trio). Relevant imaging parameters [3] with b-SSFP readout were: spatial resolution = 3.3 mm x 3.3 mm, temporal resolution = 35 ms, flip angle = 20 (optimized for myocardial signal), and breath-hold duration = 24 heart beats. Each data set was retrospectively undersampled to simulate acceleration (R) factors (R = 4 and 8), which could be used to increase spatial and temporal resolution and/or reduce breath-hold durations down to 6 and 3 heart beats, respectively. Figure 1 shows random ky-t undersampling patterns for R = 4 and 8, where the edges of k-space are sampled with progressively lower density. Each undersampled data set was reconstructed offline using the parameters outlined in reference [6], where temporal Fourier transform and temporal total variation were used as two orthogonal sparsifying transforms with normalized regularization weights 0.001 and 0.01, respectively. The resulting cine DENSE data were processed with echo-combination reconstruction, in order to calculate the circumferential shortening strain (Ecc), as previously described [3]. The same endo- and epi-cardial contours were used for each subject for the different acceleration factors in order to eliminate errors arising from different segmentation processes. We performed Bland-Altman analysis to evaluate agreement in the resulting Ecc values.

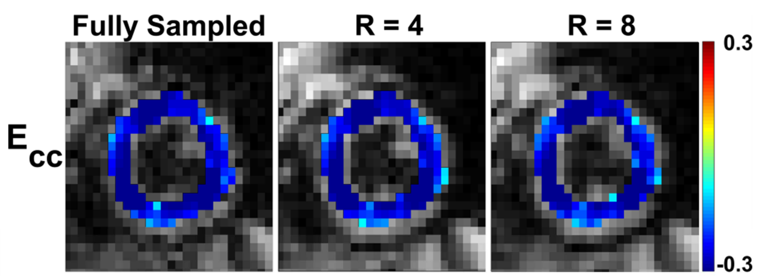

Figure 2: End-systolic Ecc maps of a subject at (left) R =1, (middle) R= 4, and (right) R =8.

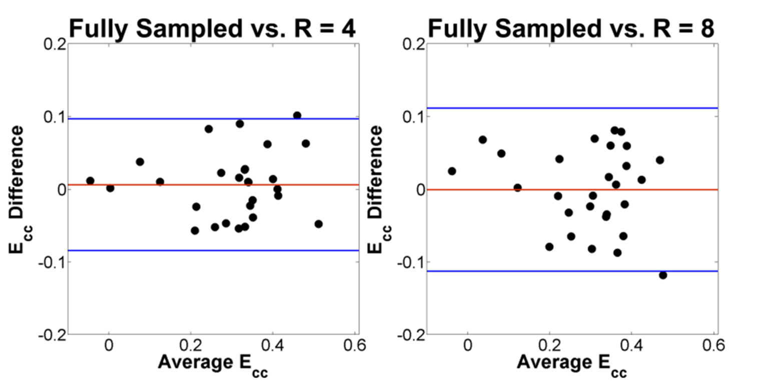

Figure 3: Bland Altman analysis showing agreement (left) between R =1 and R = 4 and (right) between R = 1 and R = 8.

Results: Figure 2 shows end-systolic Ecc maps of one subject in mid-ventricular short-axis plane at the different acceleration factors. Compared with fully sampled Ecc maps, both 4- and 8-fold accelerated Ecc maps yielded good data agreement (Fig. 3), though the confidence intervals increase with data acceleration as expected.

Conclusion: Our simulation study shows that 4-fold and 8-fold accelerated cine DENSE MRI with k-t SPARSE SENSE yields relatively accurate Ecc measurements. For more accurate Ecc results, it may be prudent to perform 4-fold accelerated cine DENSE MRI. Depending on the application, the additional acceleration gained with k-t SPARSE-SENSE may be utilized to increase spatio-temporal resolution. Future work will be focused to prospectively evaluate the method in patients with wall motion abnormalities.

References: [1] Aletras AH, et al. J Magn Reon. 1999; 137(1):247-52. [2] Kim D, et al. Radiology. 2004; 230(3):862-71. [3] Kim D, et al. NMR in Biomed. 2007; 20:591-601. [4] Feng L, et al. MRM. 2009; 62:682-690. [5] Otazo R, et al. MRM 2010; 64:767-776. [6] Feng L, et al. Magn Reson Med. 2013 Jul; 70(1):64-74.