Left Ventricular Function in a Single Breathhold with 3D Radial CINE bSSFP and 3D Through-time Radial GRAPPA

Kestutis Barkauskas[1], Vidya Nadig[2], Bruce Spottiswoode[3], Sven Zuehlsdorff[3], and Nicole Seiberlich[1]

[1]Biomedical Engineering, Case Western Reserve University, Cleveland, Ohio, United States, [2]Heart and Vascular Center, Metro Health Hospital, Cleveland, Ohio, United States, [3]Cardiovascular MR R&D, Siemens Medical Solutions, Chicago, Illinois, United States

TARGET AUDIENCE: Cardiologists and radiologists who employ MRI to perform Left Ventricular (LV) functional studies.

PURPOSE: To show that 3D Through-time Radial GRAPPA [1] can: (1) reconstruct cine images of the entire heart using angularly undersampled 3D single-shot radial data acquired in a single breathhold; and, (2) demonstrate equivalent left ventricular (LV) ejection fraction (EF) estimates as the clinical gold-standard 2D segmented cine scans in healthy volunteers.

METHODS: Ten healthy volunteers were recruited to participate in this IRB approved study. All imaging was performed on a 1.5T MR scanner (MAGNETOM Espree, Siemens Healthcare, Erlangen, Germany) using a body and spine array combination (15 to 18 channels depending on orientation). The gold-standard ECG-gated 2D segmented cine bSSFP sequence required six breathholds over a period of 3-5min to collect 12 slices (TE 1.65ms, thickness 8mm, gap 0mm, flip angle 70°, FOV 292x360mm^2, matrix 104x256, BW 977Hz/pix, temporal resolution 43ms per cardiac phase from data acquired over 8 heartbeats per slice). The alternative approach used 3D single-shot radial cine bSSFP with a stack-of-stars cylindrical trajectory and parallel imaging acceleration via 3D Through-time Radial GRAPPA. ECG-gated 3D cine volumes were collected with an angularly undersampled acquisition (16 projections for 128^2 matrix, TE 1.58ms, flip angle 40°, FOV 256x256mm^2, BW 1116Hz/pix, temporal resolution 51ms per cardiac phase from data acquired over 16 heartbeats per volume). Oversampling of 33% was used to eliminate aliasing in the partition direction, where the entire heart was imaged using just the central 12 of 16 partitions to yield the same slice coverage (i.e. 96mm) as the 2D approach. This required a single breathhold of 17 cardiac cycles (including 1 dummy cycle) to acquire 13-20 cardiac phases. The calibration data was comprised of 10 repetitions of an ungated, free breathing, fully-sampled (208 projections) acquisition with the same basic 3D radial sequence parameters (acquisition time of 1m 56s). 3D Through-time Radial GRAPPA was used to reconstruct the undersampled volumetric data (segmentation: radial 4, angular 1). Following the parallel imaging reconstruction, each partition was gridded using the IRT toolbox [2] in Matlab (R2011b, The Mathworks, Nattick, MA). For both methods on each subject, ejection fraction was estimated by segmenting the LV (including the papillary muscles) to extract end-systolic and end-diastolic volumes (Argus, Siemens Healthcare, Erlangen, Germany). Differences between the two methods were evaluated for significance with a Bland-Altman analysis.

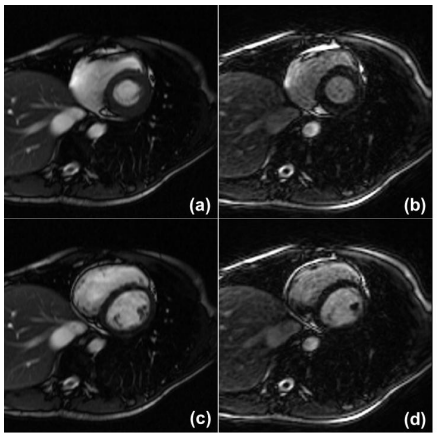

Fig. 1: Timeframes for EF calculation. Image quality is sufficient to draw endocardial contours at end-systole (a,b) and end-diastole (c,d) for both 2D segmented cine (a,c) and 3D radial cine (b,d).

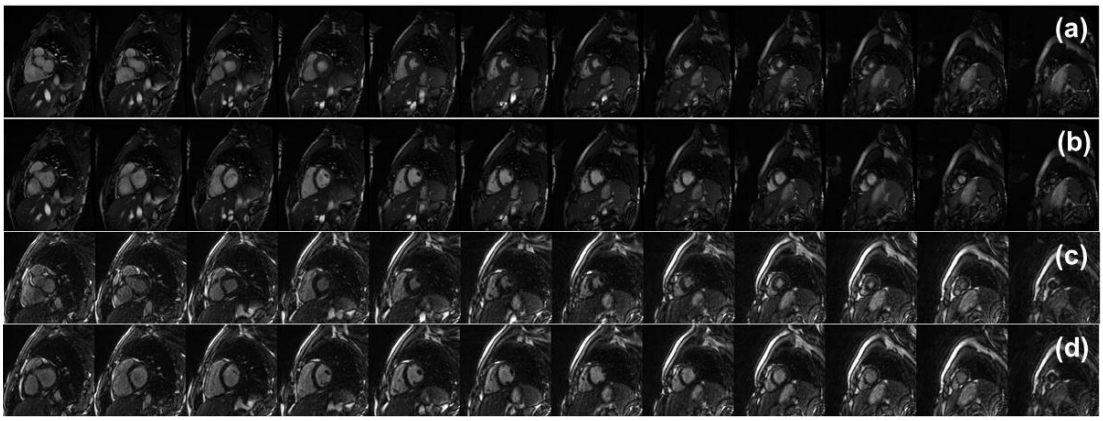

Fig. 2: Whole heart coverage. Uniform blood myocardium contrast was observed in both 2D segmented cine (a,b) and 3D radial cine (c,d) at end-systole (a,c) and end-diastole (b,d).

RESULTS: Figure 1 shows one partition for a representative subject for 2D segmented cine (a,c) versus 3D radial cine (b,d) scans at end-systole and end-diastole, respectively. Figure 2 shows whole heart coverage in a different subject for 2D segmented cine (a,b) versus 3D radial cine (c,d) scans at end-systole and end-diastole, respectively. Bland-Altman analysis (Figure 3) shows that differences (3D radial – 2D segmented) between EF estimates are not statistically significant (mean +/- 1.96*SD of bias: 0.7 +/- 5.5%).

DISCUSSION: Despite an 8-fold acceleration relative to a Cartesian acquisition, the 3D radial cine method achieved equivalent estimates for EF in a single breathhold and in less total scan time than the 2D cine multi-breathhold gold-standard. For patients, the 3D radial cine method should be easier to complete as only one breathhold is required; however, this technique relies on the same presumption of periodic motion over several cardiac cycles as the 2D cine gold-standard. This work applied the parallel imaging reconstruction method 3D Through-time Radial GRAPPA in lieu of iterative, non-linear and constrained reconstructions of the angularly undersampled volume. Calibration times could be further reduced via additional segmentation or angular undersampling of the calibration trajectory. Furthermore, the partition direction can be readily undersampled to shorten the duration of the single breathhold for symptomatic patients.

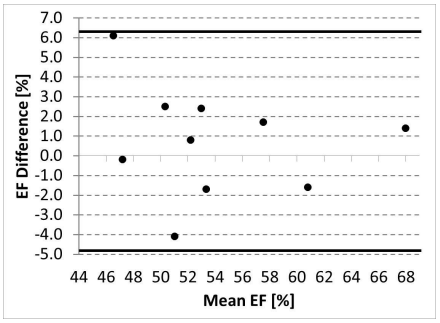

Fig. 3: Bland-Altman plot. All EF differences (3D Radial – 2D Segmented) are within acceptable limits (solid black lines).

REFERENCES: [1] Seiberlich, et al. Proc ISMRM 2012. Pg. 3838, [2] http://web.eecs.umich.edu/~fessler/code

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