A Qualitative and Quantitative Assessment of Real-Time Cardiac Functional Imaging using Through-Time Radial GRAPPA

Vidya Nadig[1], Victoria Yeh[2], Gunhild Erstad Aandal[3], Prabhakar Rajiah[3], Trevor Jenkins[4], Abdus Sattar[5], Mark Griswold[3,6], Vikas Gulani[3,6], Robert Chapman Gilkeson[3], and Nicole Seiberlich[6]

[1]Cardiology, MetroHealth Medical Center at Case Western University, Cleveland, OH, United States, [2]Case Western Reserve University School of Medicine, Cleveland, OH, United States, [3]Dept. of Radiology, Case Western Reserve University and University Hospitals of Cleveland, Cleveland, OH, United States, [4]Cardiology, University Hospitals of Cleveland, Cleveland, OH, United States, [5]Epidemiology and Biostatistics, Case Western Reserve University, Cleveland, OH, United States, [6]Biomedical Engineering, Case Western Reserve University, Cleveland, OH, United States

Target audience: Clinicians who use cardiac MR (CMR) for functional assessment of the left ventricle.

Purpose: Current CMR techniques which rely on cardiac gating and breathholds have limited utility in patients who have arrhythmias or difficulty with breathholding. By using through-time radial GRAPPA[1], a non-Cartesian parallel imaging method, highly accelerated CMR can be performed with temporal resolutions of < 50ms/slice, precluding the need for gating or breath-holding. We tested the hypothesis that volumetric measurements in the left ventricle (LV) obtained with this real-time method could replace traditional measurements, and performed a radiologist comparison study to assess the image quality of the real-time scans in comparison to the gold-standard.

Methods: A total of 41 subjects (32 patients, 9 volunteers) were scanned on a 1.5T Avanto or 1.5T Espree scanner (Siemens Medical Solutions, Erlangen, Germany) with a body and spine array combination (12 to 18 channels). The standard short-axis cardiac functional examination was performed with ECG gating, 12-16 breathholds with the following patient-dependent parameters: Cartesian bSSFP sequence, temporal resolution~31-62ms, in-plane resolution=1.4-2.6mm^2, slice thickness=8mm, cardiac phases=18-30. The real-time scans were performed following the gold-standard scan with no ECG gating or breath-holding and the following sequence parameters: radial bSSFP sequence, TR=2.64ms, resolution=2.3mm^2, slice thickness=6-8mm to match the Cartesian imaging, temporal resolution of 42.2ms per image, acceleration factor of R=8 with respect to Cartesian bSSFP (16 projections for 128^2 matrix). A total of 26 calibration frames for the through-time radial GRAPPA reconstruction were acquired without ECG gating or breathholds and the reconstruction used a through-k-space segment size of 8x4 (read vs projections). After data reconstruction, the anonymized images were presented to two radiologists for independent review. Parameters that they rated included endocardial border definition, mitral valve and papillary muscle visualization, myocardial abnormalities, blood pool contrast, cardiac motion, presence of artifact. The scale that was used for rating was visualization excellent/visualization good/visualization poor/no visibility. Images were also reviewed for presence of artifact and if their presence affected volumetric analysis. Volumetric analysis of the left ventricle was performed (Argus Ventricular Function software, Siemens Medical Solutions).

Results: Bland-Altman analysis[2] was used to analyze the agreement in end diastolic volume, end systolic volume, and ejection fraction calculated from the two acquisition methods. One patient was excluded from the analysis due to severe arrhythmia which led to detrimental artifacts in the gold-standard breathhold images (although the real-time images showed no artifacts). Thirty-nine out of 40 of the EF measurements using breathhold imaging and the free-breathing method were within the 95% limits of agreement. The mean difference in LVEF between the two methods was -1.9% (breathhold minus real-time). 40/40 and 39/40 measurements of EDV and ESV were within 95% limits of agreement, and the mean differences between the two methods were -2.0mL and 2.6mL, respectively. Results of the radiologists' review, based on an ordinal logistic regression analysis (corrected for clustering) of the radiologists' ratings, the real-time method depicts the endocardial borders better than the breathhold method ($p<0.05$). Cardiac motion and visualization of papillary muscles and endocardial border showed no statistical difference ($p>0.05$), although mitral valve visualization and blood pool contrast were better ($p<0.05$) when using the breathhold method. For both reviewers, different qualitative parameters (visualization of endocardium, papillary muscle, mitral valve, blood pool contrast, myocardial abnormalities and cardiac motion) for the real-time images were mostly rated in the excellent or good visibility range (81% excellent and 18% good for real-time vs. 95% excellent and 5% good for breathhold).

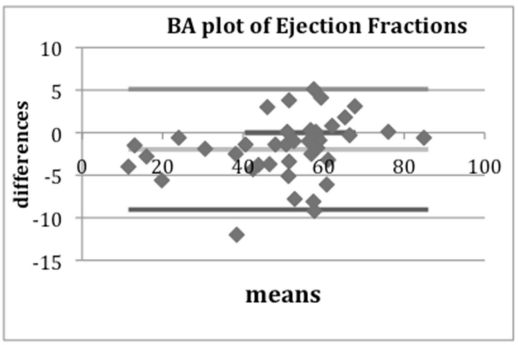

Figure 1: Bland-Altman plot comparing the Ejection Fraction values of the gold-standard breathhold method and the free-breathing real-time method.

Discussion: There is no statistically significant difference in the volumetric analysis between the two methods despite minor differences in spatial and temporal resolution[3]. The radiologists' ratings confirmed that image quality between the two types of scans is similar, and >98% of qualitative parameters for the real-time method were in the good or excellent visibility range. Because no gating or breathholding was employed in the real-time scans, artifacts from failed breathholds and/or misgating did not occur, leading to a smaller number of exams adversely affected by artifacts in comparison to breath-hold scans. This indicates that standard breathhold method could be replaced by the real-time approach, which would obviate the need for breath-holding and thus lead to increased patient tolerance, compliance, and elimination of non-diagnostic exams due to poor breath-holds. In the future, this technique could also be used for patients with arrhythmias, in whom MR-based EF measurements are not possible.

Conclusion: The results indicate that through-time radial GRAPPA imaging could be used to replace the current standard breathhold cine imaging, since there was no significant statistical or clinical difference between volumetric analysis determined between the two methods. Additionally, since the method is non-gated and free-breathing, radiologists' ratings of the real-time images demonstrated excellent image quality and fewer artifacts than breathhold imaging, thus indicating that there could also be a significant advantage of through time GRAPPA in patients with arrhythmia or difficulty with breath-holding.

Funding: Case Western Reserve University/Cleveland Clinic CTSA UL1 RR024989 and NIH/NIBIB R00EB011527. **References**: [1] Seiberlich N, et al. Magn Reson Med. 2011 Feb; 65(2):492-505. [2] Altman DG, Bland JM. The Statistician 1983 Sep; 32(3):307-317. [3] Pattynama PM, et al. Radiology 1993; 187:261–8.