# Through-Time Spiral GRAPPA for Real-Time Cardiac Imaging

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**Introduction:** Accelerated data acquisition followed by parallel imaging reconstruction has been used in cardiac imaging to reduce imaging times and avoid artifacts due to motion. Coupled with non-Cartesian trajectories, such parallel imaging techniques can yield images with high acceleration factors with little residual aliasing. Recently, a method has been proposed which improves the radial GRAPPA technique by employing a through-time calibration scheme [1]. This through time calibration involves generating GRAPPA weights by using similar kernel patterns through k-space, as in standard GRAPPA, but also through time to improve the reconstruction quality. Although frame rates of 20 frames/sec can be achieved with through-time radial GRAPPA, the k-space coverage efficiency of the radial trajectory is limited when compared to others. In contrast, spiral trajectories can be designed which offer faster traversal through k-space, thereby offering a much faster image acquisition with a lower acceleration factor than the radial trajectory. In this abstract, through-time spiral GRAPPA is demonstrated for real-time cardiac imaging with frame rates of 56 frames/sec (a temporal resolution of 17.9 ms/image, R=12).

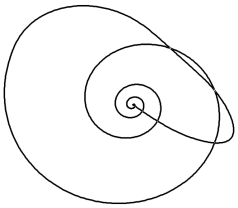

Fig 1: An example of a single variable density spiral arm used for the acquisition.

**Materials and Methods:** A spiral trajectory which covers a $128^2$ matrix in 48 spiral arms was designed using Matlab code written by Brian Hargreaves [3,4]. This variable density spiral offers full coverage of the central 10x10 region of k-space with only 4 spiral arms, and is $0^{th}$ and $1^{st}$ gradient moment compensated for flow insensitivity [5] and compatibility with a TrueFISP acquisition. This trajectory was implemented with the following parameters: FoV = $300mm^2$, TR = 4.48ms, 1000 read-out points, and data were acquired in short axis view from four volunteers with informed consent on a 1.5T Siemens Espree (Siemens Medical Solutions). The trajectory was measured using the method of Duyn et al [6]. An example of a single spiral arm with gradient refocusing is shown in Fig 1. A total of 80 fully-sampled (48 spiral arm) images for calibration were acquired of a short axis cardiac image in a healthy volunteer which lasted 17.2s. A 15-channel body array was used. Following this scan, 200 accelerated images (4 spiral arms each) were acquired; each undersampled image was acquired in 17.9ms. During both scans, the volunteer was instructed to breathe normally, and no EKG gating was employed. The undersampled spiral data were reconstructed using hybrid spiral GRAPPA (4 x 1 segments in the read x arm directions, 80 calibration frames), as suggested in [1]. The reconstructed data were gridded using the Image Reconstruction toolbox from Jeffrey Fessler (NUFFT) [7].

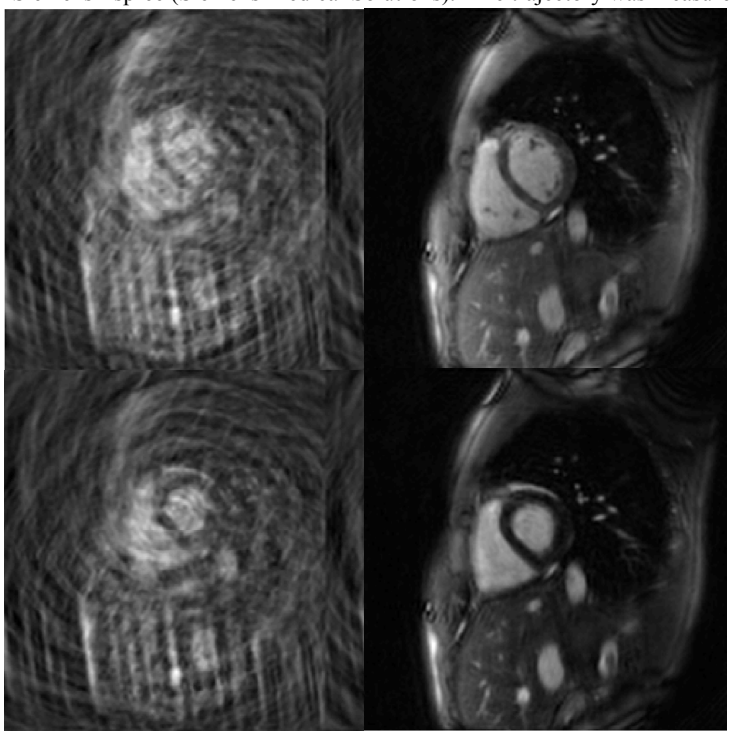

Fig 2: Examples of images acquired in 17.9ms reconstructed using standard gridding (left) and through-time spiral GRAPPA (right). It is important to note that the top images are the first image in the series, and the bottom are the 38th, and they are from the same heartbeat (which was over 70 images long in this example.)

**Results:** Example undersampled and reconstructed images acquired in diastole and systole using the spiral trajectory are shown in Fig 2. The through-time spiral GRAPPA reconstruction yields images with fewer aliasing artifacts, even at the rate of 56 frames/sec. Temporal blurring between the images is not observed.

**Discussion:** The images shown here demonstrate that the through-time calibration method for radial GRAPPA can be extended to the spiral trajectory. Because of the efficiency of this trajectory, either the same temporal resolution as the radial method can be targeted (50 ms) using a much lower acceleration factor (R=4 for spiral instead of R=8 for radial), or the temporal resolution can be further increased. The images in Fig 2 were reconstructed from 4 spiral arms, yielding a temporal resolution of 17.9ms/frame, without employing view-sharing. This work demonstrates that through-time spiral GRAPPA is an efficient alternative to radial GRAPPA, and provides images with excellent quality using high acceleration factors to achieve frame rates of less than 20ms/frame. The free breathing and non-gated nature of the acquisition indicates that such an exam may be useful when scanning patients with arrhythmias or who cannot hold their breath.

**References:** [1] Seiberlich N, et al. Magn Reson Med. 2010 [Epub Sep 24]. [2] Griswold MA, et al. Magn Reson Med. 2002 Jun;47(6):1202-10. [3] http://mrsrl.stanford.edu/~brian/mritools.html [4] Hargreaves B, et al. Magn Reson Med. 2004 51:81-92. [5] Nayak KS et al. Magn Reson Med. 2005 Jun;53(6):1468-73. [6] Duyn, et al. J Magn Reson. 1998 May;132(1):150-3.[7] http://www.eecs.umich.edu/~fessler/code/

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