3D Golden Angle Through-Time Radial GRAPPA with Self-Navigation for High Resolution 3D Abdominal Imaging

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Introduction: 3D abdominal MR imaging at high spatial resolution requires long breathholds to avoid motion artifacts, and the entire dataset can be corrupted if the patient resumes breathing during the acquisition. This is particularly problematic for timed post-contrast data, where image re-acquisition is not feasible. The Motion Artifact Removal by Retrospective Resolution Reduction (MARs) technique automatically identifies the transition between breath-holding to free breathing and retrospectively removes the corrupted data to yield a motion artifact free image at the expense of reduced resolution or streak artifacts[1]. This work seeks to retain resolution and avoid streak artifacts by using parallel imaging to reconstruct the missing projections after data rejection to flexibly use as much acquired dynamic data as possible. Here, a 3D golden angle radial trajectory ensures nearly uniform angular sampling in k-space for a breathhold of any length, where a 3D version of the golden angle through-time radial GRAPPA reconstruction[2] synthesizes the rejected projections. This combined approach yields 3D high-resolution abdominal images within a single breath-hold of arbitrary duration.

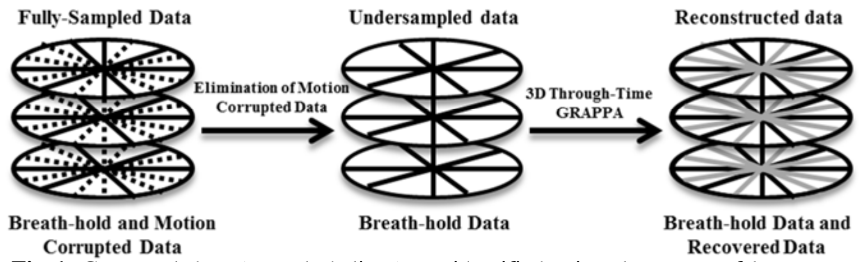

Fig 1. Corrupted data (gray dash lines) are identified using the center of k-space and removed, and the missing projections are reconstructed using 3D golden angle through-time radial GRAPPA.

Methods: Five asymptomatic volunteers, who gave written informed consent to this IRB-approved study, were asked to hold their breath for as long as possible while 3D golden angle radial data were acquired on a 3T Skyra scanner (Siemens Medical Solutions, Erlangen, Germany) using a 24-channel receive array (FLASH sequence, projections per partition = 288, readout points = 256, field-of-view = 350mm^2, base resolution = 256^2, TR/TE = 2.94/1.34ms, slice thickness = 2mm, bandwidth = 980Hz/Px, flip angle = 10°, partitions per slab = 72, partition oversampling = 22.2%). The total acquisition time for this dataset was 75 seconds. The long acquisition ensured that the volunteer will transition to breathing during the scan time. The center sample of the centermost partition for a given projection angle served as the "navigator" signal, where the transition from breath-hold to free-breathing was detected by finding the maximum difference in the so-called "echo-peak magnitude" over time. As summarized in Fig 1, only the projections prior to the transition are retained, leading to a radially undersampled dataset. The undersampled golden angle dataset was then reconstructed using 3D golden angle through-time radial GRAPPA with a segment size of 8 read points × 1 projections, 18 partitions, and 4 calibration frames acquired during free-breathing, similar to the previous study[3]. Images were gridded after reconstruction using the NUFFT[4].

Results: The echo-peak magnitude demonstrated an abrupt increase at the transition from breath-hold to motion corrupted data for all five volunteers. An example of such a transition for one volunteer is shown in Fig 2a. Fig 2b shows an image generated by using all of the golden angle data, and exhibits motion artifact as only approximately 36% of the data were collected during the breathhold. By removing motion-corrupted data, motion artifacts are obviously reduced (Fig 2c), but the subsequent undersampling (104/288 projections retained) leads to streak artifacts. After reconstruction with 3D golden angle through-time radial GRAPPA, both motion and streaking artifacts are reduced (Fig 2d).

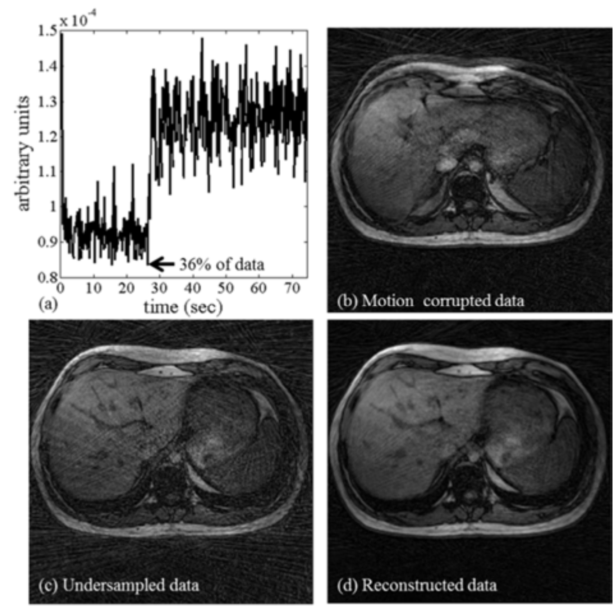

Fig 2. Representative examples of (a) echo-peak magnitude with identified transition (black arrrow) showing that motion occurred approximately 36% through total acquisition time; (b) uncorrected image with motion generated using all of the 3D data; (c) undersampled image generated using only data collected during the breathhold with streak artifact; (d) image generated after application of 3D golden angle through-time radial GRAPPA.

Discussion/Conclusion: This work has demonstrated the combination of a 3D golden angle radial trajectory and non-Cartesian parallel imaging for high-resolution abdominal imaging. This trajectory provides a "self-navigation" signal to detect the inevitable transition from breathhold to free-breathing, and the golden angle radial trajectory yields nearly uniform angular undersampling regardless of breathhold duration. In the example shown here, only 36% of the fully-sampled k-space was collected during the breathhold and retained, and 3D golden angle through-time radial GRAPPA substantially reduced the streak artifact from the undersampling. This method can automatically and retrospectively provide clinically useful images even in the presence of motion while preserving high resolution for 3D abdominal imaging. Such a method is expected to be particularly benefitial when there is a requirement for high resolution scanning that would ordinarily require an impossibly long breath-hold, for example in the characterization of small hepatic or renal lesions.

References: [1] Bookwalter et al. Proc. of ISMRM 2012, #3412. [2] Han et al. Proc. of ISMRM 2013, #3834. [3] Seiberlich et al. Proc. of ISMRM 2013, #3838. [4] Fessler JA. J Magn Reson. 2007;188(2):191–195. **Acknowledgements:** Siemens Healthcare and NIH grants NIH/NIBIB R00EB011527 and 1R01DK098503.