Application of Golden Angle Radial 3D Gradient Echo with k-Space Weighted Image Contrast (KWIC) for Motion-Insensitive Hepatic Arterial-Phase Imaging: Initial Experience

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Target Audience. Body Radiologists. Clinical Physicists.

Purpose. The hepatic arterial-phase of an abdominal MR exam is the most important acquisition to visualize malignant tumors and other hyper-vascular liver lesions. Ideally, a single or multiple volumetric T1-weighted datasets (3D GRE) are acquired during a breath hold over a specific bolus-timed window. However, this strategy is compromised in a subset of patients with reduced breath holding capability, and few solutions exist to provide motion-resistant alternatives. Recently, 3D GRE with radial sampling ("stack of discs") has shown reduced motion sensitivity in free-breathing subjects using fully-sampled radial datasets (1). The purpose of this investigation was to configure and implement radial 3D GRE for hepatic arterial-phase acquisitions, using "golden angle" radial scheme acquisition, along with temporal view sharing.

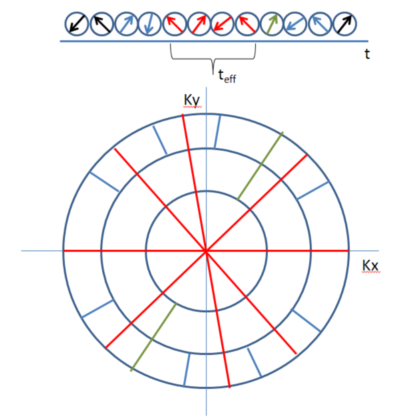

Figure 1. Golden Angle scheme with temporal reconstruction

Methods. All sequence implementations were performed on a Siemens 1.5T (Aera) and 3T (Skyra) system (Erlangen, Germany), using a radial 3D GRE, modified to utilize a golden angle acquisition strategy, coupled with k-space weighted image contrast (KWIC) (2). The golden angle acquisition scheme enables uniform radial k-space sampling by employing a constant 111.2 degree increment angle. Temporal blurring is reduced by dividing k-space into concentric rings, and distributing acquisition data such that the Nyquist criterion is satisfied for each ring. Since the criterion increases with k-space radius, all views within a time window are used in the outer ring, while a smaller subset of radial views is used for inner rings (Fig 1). The center-most ring contributes to the effective temporal resolution, t_{eff}, and uses the least number of specified radial views.

Motion-resistant golden angle dynamic 3D GRE (Dyn-radGRE) was implemented with following parameters: 88 slices, 3mm thickness, 288 matrix, FOV=380mm, BW=600-700Hz/px. Depending on 1.5T or 3T, the flip angle, TR and TE were optimized for image contrast and fat suppression (10-12 degrees, 3.3-4.0ms/1.5-2.2ms). The number of total radial views was set to 544 to 680, which enabled both sufficient fully-sampled datasets, and an overall scan time needed to encompass both arterial and venous-phase imaging (90 sec). For KWIC reconstruction, t_{eff} was minimized (5-6 sec), while providing a sufficient number of central-ring radial views (34 views). Furthermore, 3 time intervals were selected, each with a prescribed number of temporal sub-frames: 1) pre-contrast, 1 frame (0-12sec); 2) arterial-phase, 5 frames (12-37 sec); and 3) venous-phase, 1 frame (50-90 sec).

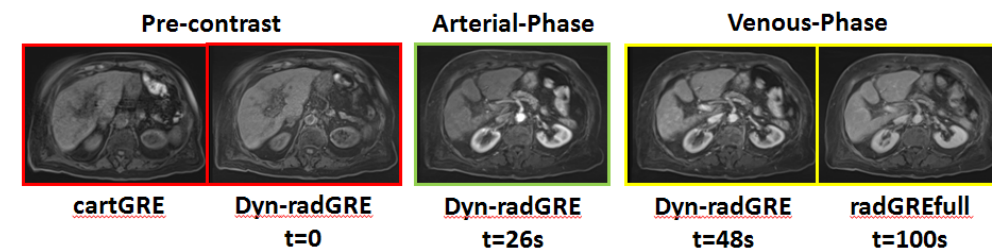

Figure 2. Selected phases of Dyn-radGRE in one patient

All subjects provided written informed consent prior to imaging. Dyn-radGRE was implemented prospectively in three patients (1 female, age range, 32 to 84yrs) with clinically indicated abdominal exams and reduced breath hold capacity. Two patients were performed at 3T. Patients were instructed to breathe quietly during acquisition. Dyn-radGRE was initiated simultaneously with 0.05mmol/kg gadobenate dimeglumine (Multihance, Bracco) at 2cc/s. For comparison, both fully-sampled radial 3D GRE (radGREfull, 320 matrix, 504 views, 96slices, 3mm thick, flip/TR/TE = 10/3.7/1.7ms, t=90sec) and accelerated Cartesian 3D GRE (cartGRE, 288x173, 96slices, 3mm thick, flip/TR/TE = 10/3.1/1.2ms, t=11sec) were acquired pre-contrast, while radGREfull was also acquired post-contrast (venous-phase). Since identical first-pass imaging phases were not acquired among the methods, arterial sub-frames from Dyn-radGRE were analyzed qualitatively for optimal timing features, along with the presence of significant artifacts. In addition, pre-contrast and venous-phase Dyn-radGRE were compared to corresponding radGREfull and cartGRE phases using a subjective image quality score (poor, acceptable, and superior).

Results and Discussion. All Dyn-radGRE acquisitions were performed without complication. Optimal arterial-phase was identified in 2/3 patients. Dyn-radGRE was not able to capture the arterial-phase in one patient due to delayed contrast transit time. Figure 2 compares pre-, arterial-, and venous-phases from Dyn-radGRE with cartGRE and radGREfull in one patient with chronic liver disease. As shown, cartGRE is subject to pronounced motion artifacts, which is ameliorated with Dyn-radGRE. The arterial-phase sub-frame also shows minimal motion degradation, with clear distinction of hepatic arteries. Though radGREfull provides improved edge-sharpness and reduced streaking artifact, venous-phase Dyn-radGRE shows comparable image contrast and vascular structures. These imaging features and observations were consistent in the other patients, with Dyn-radGRE showing acceptable image quality on all 3 time intervals, while pre-contrast cartGRE was only acceptable in 1/3 cases. Fully-sampled radGRE exhibited superior image quality in all three patients.

Conclusions. With this preliminary experience, radial 3D GRE with golden angle acquisition scheme and KWIC reconstruction has been shown to be a viable alternative for motion-resistant arterial-phase liver acquisitions in compromised patients.

References.

1. Chandarana H, et al. Invest Radiol 2011;46(10):648-53   2. Song HK, et al. MRM 2000;44(6):825-32