HIGHLY-ACCELERATED REAL-TIME T_2-WEIGHTED IMAGING WITH RADIAL GRAPPA AND LOW-LATENCY GPU RECONSTRUCTION

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TARGET AUDIENCE: MR physicists and interventional radiologists interested in real-time imaging with T_2 contrast.

PURPOSE: T_2-weighted (T_2W) images have widespread application in MRI and are particularly valued in interventional MRI.[1–3] However, most existing T_2W imaging techniques are much slower than other competing imaging modalities used in interventional guidance, e.g. ultrasound (50 fps) and X-ray fluoroscopy (7 fps).[4,5] Thus, a real-time, high temporal resolution T_2W imaging sequence, namely T_2-weighted radial interrupted balanced steady-state free precession (T_2W-riSSFP), is proposed and tested for the visualization of myocardial edema.

THEORY: T_2W-riSSFP acquires single-shot images using 180° flip angles and samples k-space with a radial trajectory to permit a higher undersampling rate.[6] T_2 decay during radial imaging may lead to contaminated image contrast since every readout crosses through the center of k-space.[7] Additionally, streaking artifacts can occur if conventional undersampling is used. Hence, reducing the number of sampled projections with highly accelerated pre-calibrated acquisitions can minimize both these effects by reducing overall imaging time, minimizing signal decay while acquiring data and removing streaking artifacts. Note that for the radial sampling trajectory, we define TE-effective as the time from the beginning of the train to the median imaging echo.

METHODS: T_2W-riSSFP incorporates through-time radial GRAPPA for high temporal resolution,[8] and was implemented on a 48-core, 128GB RAM computer equipped with a GPU (Tesla C1060 , NVIDIA), which allowed 10-20 fps image acquisition with 20 ms latency reconstruction and inline image display.[9] Scans were performed at 1.5T (Avanto, Siemens, Germany). A 15-channel head and neck coil was used for the head scans of human subjects; a 15-channel chest array matrix was used for phantom, abdominal (human), and cardiac (swine) imaging. T_2W turbo spin echo (T_2W-TSE) was used to assess the degree of T_2W achieved. In all imaging experiments, T_2W-TSE and T_2W-riSSFP were scanned using a 192x192 image matrix, 250-300 mm FOV, and 60– 80 ms TE effective. Eight-fold radial GRAPPA acceleration was used for T_2W-riSSFP imaging. *Phantoms:* Agar gels with clinically relevant T_1/T_2 were scanned. Their T_1s/T_2s of tubes #1-6 and a $CuSO_4$-doped water were: 160/20, 140/20, 200/25, 1570/60, 2390/110, 2240/305, and 270/365 ms, respectively. Image contrast (defined as $(I - I_b)/I_b$, where I and I_b were the average intensities of the ROIs on one of tubes #2-6 and tube #1, respectively)[10,11] was calculated on both T_2W-TSE and T_2W-riSSFP. For assessment of variability, 25 metrics were calculated from 50 ROIs on five repeated scans of the same phantom. Linear regression was used to evaluate T_2-contrast of T_2W-riSSFP relative to T_2W-TSE.[12] *Normal Human Subjects: In vivo* scans were performed with IRB approval. To evaluate T_2 contrast of different organs, normal human subjects (N=5) were scanned. *Animal Model:* Swine with acute myocardial infarction (N=2) were imaged. Segmented ECG-gated breath-hold T_2W-TSE with 80 ms TE was used as the reference and compared to free-breathing ECG-triggered single-shot T_2W-riSSFP with 80 ms TE effective and 3 ms TR. Three slices were acquired for every heart beat and each slice required 44 ms magnetization preparation and 72 ms of imaging.

RESULTS: Fig. 1a and b show the images of phantom from T_2W-TSE and T_2W-riSSFP. For each tube, the intensities in a and b were similar. This is verified by the linear regression of their image contrasts: $y = 0.99x + 0.06$ and $R^2 = 0.998$. Fig. 1c and d present the brain images of a normal human subject acquired by T_2W-TSE (c) and T_2W-riSSFP (d). Similar image contrasts between fluid, gray matter and white matter are seen in these two images. Short axis view of a swine heart from T_2W-TSE (breath-hold) and T_2W-riSSFP (free-breathing) are shown in Fig. 1e and f. The edema at septum (red arrow in Fig 1e and f) is depicted in both e and f. Note the slow blood flow artifact of T_2W-TSE (green arrow in Fig 1e) and the difference in acquisition time.

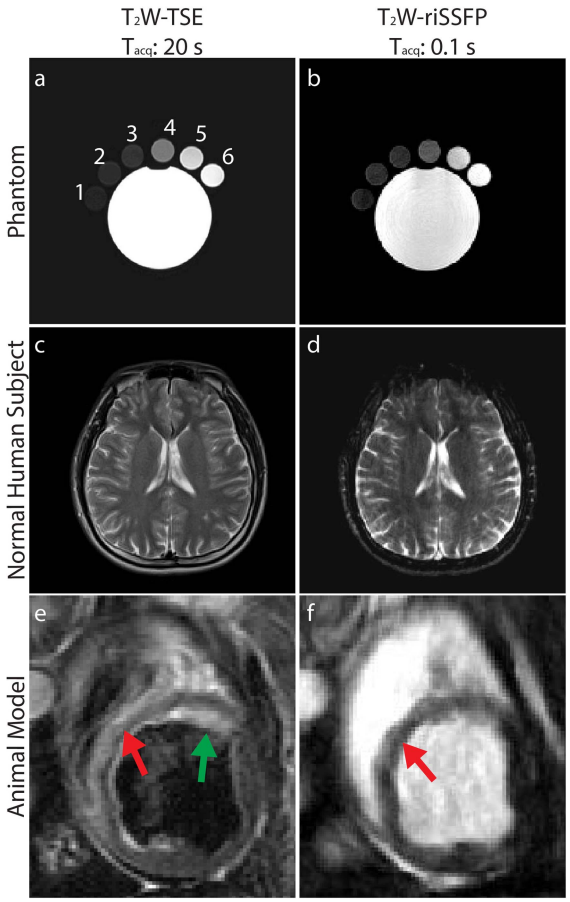

Figure 1: Comparison of T_2W-TSE and T_2W-riSSFP. Images of phantom (a & b), a normal human subject (c & d), and a swine after acute myocardial infarction (e & f) demonstrate similar contrast. Edema (red arrow in e & f) can be observed in f even though acquisition time (T_{acq}) was significantly shorter. The green arrow in e shows the slow blood flow artifact of T_2W-TSE.

CONCLUSION: T_2W-riSSFP offers high temporal resolution real-time T_2-weighted imaging. T_2W-riSSFP can be applied in real-time cardiac interventions where heavily T_2-weighted images are needed such as the assessment of acute injury due to myocardial infarction or RF ablation.

FUNDING: This project was funded by Siemens and NIH/NIBIB R00EB011527 **REFERENCES:** 1. Kellman et al MRM 2007; 2. Vergara et al Heart rhythm 2010; 3. Simonetti et al Radiology 1996; 4. Cannon et al Comp. Aid. Surg. 2003; 5. Fahrig et al Acad. Rad. 2001; 6. Paul et al MRM 2006; 7. Althach et al JMRI 2002; 8. Seiberlich et al MRM 2011; 9. Saybasili et al ISMRM 2013; 10. Peli et al Opt. Img. Sci. 1990; Moseley et al MRM 1990; 12. Rodgers et al Ame. Stat. 1988.