

Accelerated, motion-corrected high-resolution intravascular MRI at 3T

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Audience: Interventionalists, and those interested in atherosclerosis and intravascular MR imaging.

Purpose. Current speeds for intravascular (IV) MRI and MRI endoscopy¹ are limited to ~2frames/s at 3T, rendering high-resolution (~100 μ m) images susceptible to degradation by physiological motion on the order of mm/ms. Here, using projection reconstruction we: (A) reduce sensitivity to motion from the time-scale of individual images, to the time-frame of each projection (TR) by frame-shifting each projection to the antenna, prior to reconstruction. In addition: (B) we apply compressed sensing to provide acceleration factors of up to four-fold. We present data acquired in phantoms (fruit), human vessel specimens and/or apply the methods to retro-actively acquired data as we move toward prospective acquisitions *in vivo*.

Methods: IV MRI with and without mechanical motion, is performed on a Philips 3T scanner using a 2mm diameter 3T loopless antenna receiver, and radial k-space traversal. For motion correction (A), we note that in each projection, there is intense signal surrounding the probe, but the probe itself produces no signal. Further, there is a phase reversal that occurs at the probe (Fig. 1 a, d). These amplitude and phase singularities at the probe's location are detected using a signal derivative algorithm, and used to align all the projections (Fig. 1f). Images reconstructed from these, always have the probe at the center of the field-of-view. Compressed sensing (B), is performed on projection images using uniform under-sampling², while variable-density random under-sampling is used on previously-acquired *in vivo* Cartesian data¹. Images are reconstructed using " ℓ_1 -norm" minimization and wavelet transform^{2,3}.

Results: Motion correction significantly reduces motion artefact compared to conventional reconstruction (Fig. 1b vs. 1c). Radial and Cartesian compressed sensing produced virtually indistinguishable images with only 1/4th to 1/3rd of the original data (Fig. 2, 3). Since the motion correction algorithm acts on each projection, it was also applied to a radially under-sampled data set (not shown).

Conclusions: 3T IV MRI detectors are ideally suited to compressed sensing and motion correction strategies based on their intrinsically radial and sparsely-localized sensitivity profiles and high signal-to-noise ratios. The benefits are much faster IV MRI—approaching real-time (~10 fr/s) and reduced motion sensitivity, while retaining the high-resolution (80-300 μ m) image information.

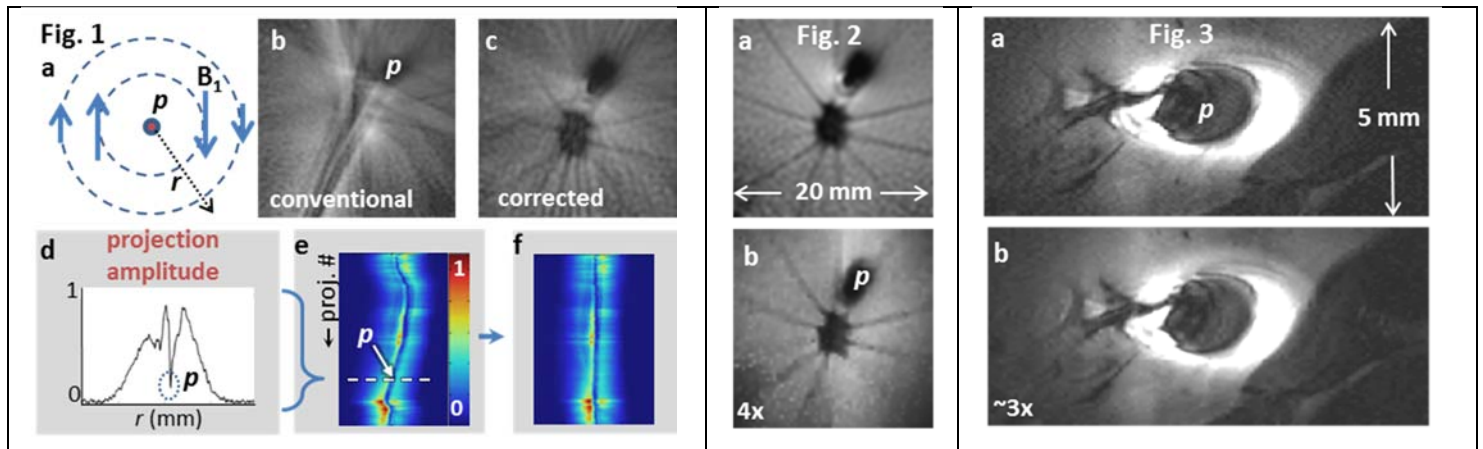


Figure 1: (a) Transverse field of a loopless antenna detector p shows decreasing B_1 with r and azimuthal variation in phase. (b) MRI of an orange shaken ± 3 mm (2D radial GRE; 200 spokes spanning 180° ; $250\mu\text{m}$ in-plane resolution; $\text{TR}/\text{TE}=15/6$ ms) shows debilitating motion artifacts. (c) Projection shifting all but removes streaking, revealing the fruit's underlying structure. A $1/r$ intensity filter has been applied to aid visualization. (d-f) The motion correction algorithm consists of re-aligning every azimuthal projection on p . **Figure 2:** Fruit morphology using the complete data set (a), is retained in a four-fold under-sampled radial-compressed sense reconstruction (b). **Figure 3:** (a) Regular Cartesian MRI endoscopy of a rabbit aorta *in vivo* (3D GRE; $\text{TR}/\text{TE}=250/12$ ms; in-plane resolution $80\mu\text{m}$; 3.1 min/5 contiguous slices). (b) Three-fold under-sampling yields a virtually indistinguishable image (cropped for visualization) after compressed-sense reconstruction.

References: (1) Sathyanarayana S, et. al., JACC Cardiovasc Imaging. 2010; 3(11):1158-1165. (2) Block et. al, Magn Reson Med 2007; 57: 1086-1098. (3) Lustig et. al, Magn Reson Med, 2007;58(6):1182-1195. Support: NIH R01 HL090728.