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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 endoscopy[1] are limited to ∼2frames/s at 3T, rendering high-resolution (∼100μm) 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-sampling[2], while variable-density random under-sampling is used on previously-acquired *in vivo* Cartesian data[1]. 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

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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 (80-300μm) image information.

Acknowledgments

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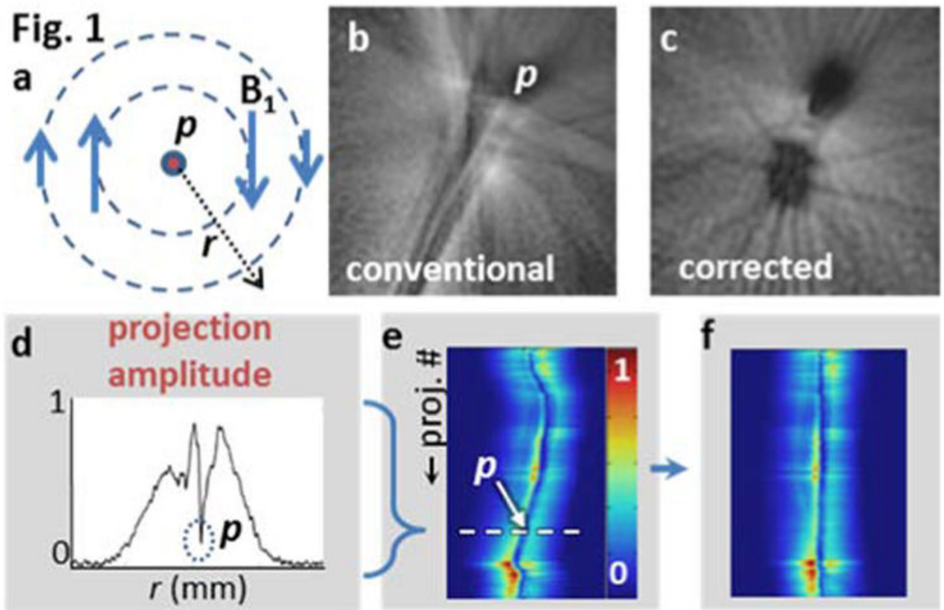

Figure 1.

(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 ± 3mm (2D radial GRE; 200 spokes spanning 180°; 250µm in-plane resolution; TR/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*.

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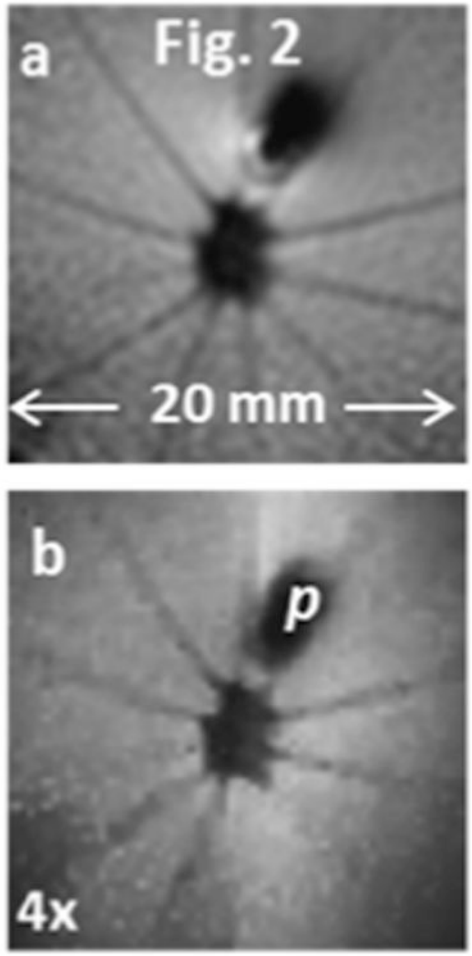

Figure 2.

Fruit morphology using the complete data set **(a)**, is retained in a four-fold under-sampled radial-compressed sense reconstruction **(b)**.

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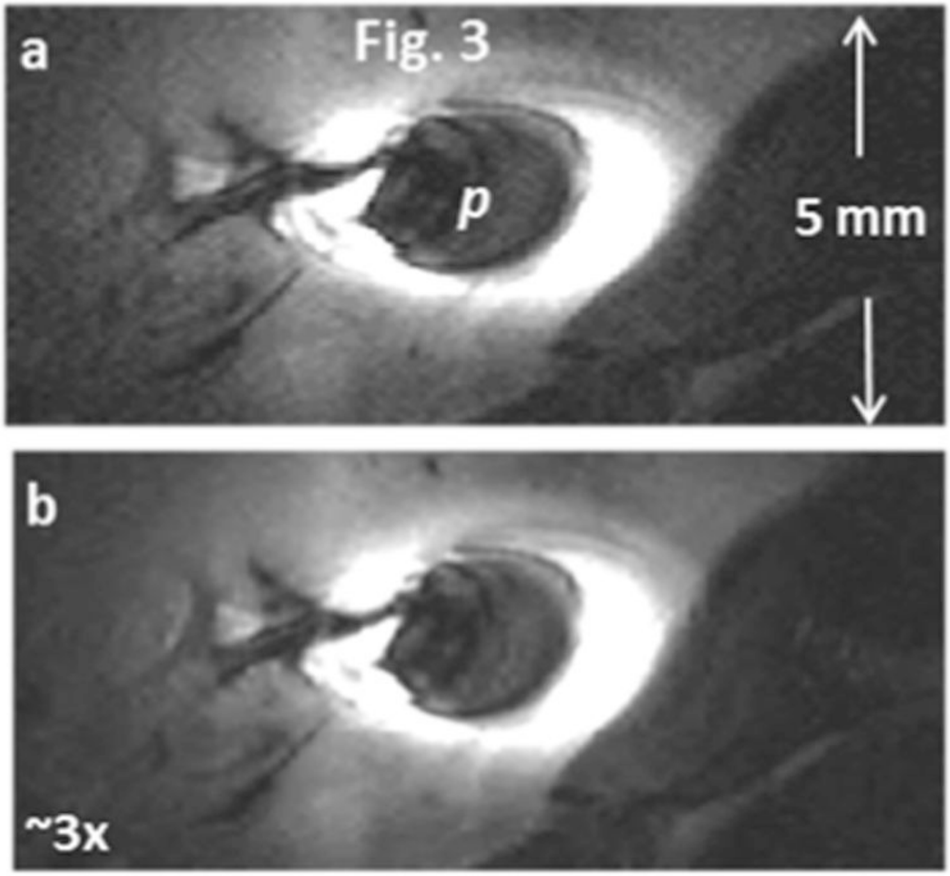

Figure 3.

(a) Regular Cartesian MRI endoscopy of a rabbit aorta *in vivo* (3D GRE; TR/TE=250/12 ms; in-plane resolution 80µm; 3.1 min/5 contiguous slices). **(b)** Three-fold under-sampling yields a virtually indistinguishable image (cropped for visualization) after compressed-sense reconstruction.