MR inverse imaging at 7T has higher spatial resolution than at 3T

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TARGET AUDIENCE Scientists interested in high-field fast fMRI acquisition strategies

INTRODUCTION Magnetic resonance inverse imaging (InI) [1] is a method of fast fMRI. By using highly parallel MRI detection, the spatial encoding of MRI by gradient is replaced by radio-frequency coil array sensitivity. Using a 32-channel head coil array at 3T, we have demonstrated that InI allows whole-brain fMRI with 100 ms TR and approximately 5 mm spatial resolution at cortex [2]. InI can be considered as a dynamic MRI method trading off spatial resolution for temporal resolution. To improve the spatial resolution of InI without slowing down the sampling rate or reducing the field-of-view, tailored reconstruction methods have been proposed [3-5].

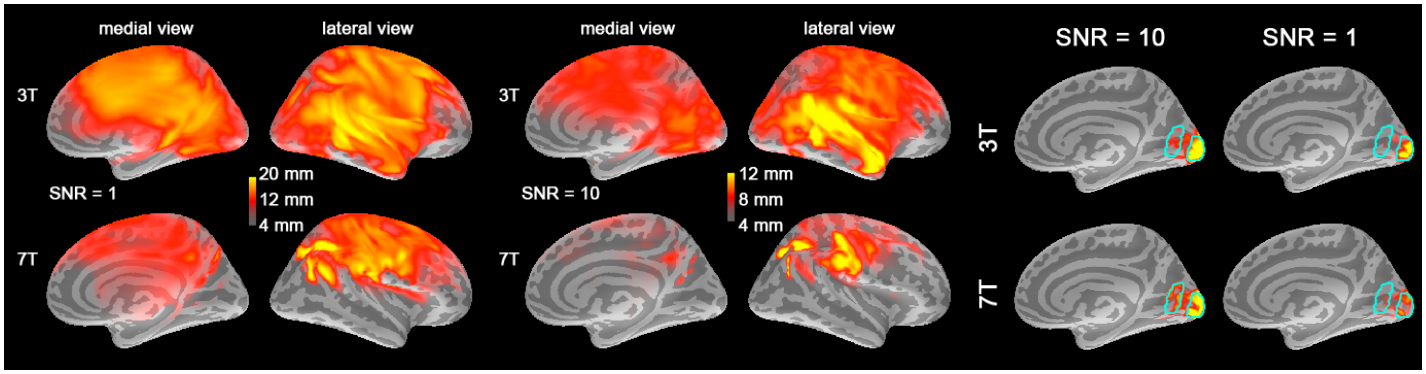
Here we propose that InI acquired at a higher field can improve its spatial resolution, because the electromagnetic theory suggests that, by using a coil array of the same geometry and the number of coils, the coil sensitivity is more disparate when the wavelength is shorter [6,7]. More independent coil sensitivity is helpful in improving the condition of the encoding matrix of MRI and consequently the spatial information can be better resolved. We specifically test this hypothesis by measuring InI data at 3T and 7T. Results support this hypothesis: the average point-spread function (aPSF) at 7T is 80% of that at 3T, suggesting that the spatial resolution is higher at 7T than at 3T.

METHODS InI data was respectively acquired at 3T Skyra and at 7T MRI scanner (Siemens Healthcare, Erlangen, Germany). A 32-channel head coil array was used for data acqusition (3T: Siemens, Erlangen, Germany; 7T: Nova Medical, Wilmington, MA, USA). A reference scan of InI was acquired from each scanner using a multi-shot echo-volumar imaging (EVI): TR=100 ms; TE=30 ms; flip angle=30o; bandwidth: 2442 Hz/px; FOV: 256 mm; image matrix: 64x64. High resolution anatomical MRI was also acquired for each subject using the MPRAGE sequence in order to allow morphing the analysis results onto a standard cortical surface coordinate system [8,9].

Fast InI acquisitions were simulated by discarding all but the central partition of the InI reference scan. Complex-valued Gaussian noise was added in order to simulate realistic acquisitions with various SNRs (0.01, 0.1, 1, and 10). Images were reconstructed using the minimum-norm estimate [2]. To quantify the spatial resolution, we first reconstructed InI with a point source, realized by a discrete delta function, in chosen location. Then averaged point-spread function (aPSF) [2] was calculated. The process was repeated for different source locations across the whole brain. We also simulated two areas in the right visual cortex and reconstructed InI to test if we can resolve their distributions.

ESULTS The figure below at left shows the spatial distribution of aPSF for SNR = 1 and 10. Low spatial resolution (with high aPSF value) was found at medial aspect of the cortical surface, insula, sensorimotor, and parietal cortices. These areas are physically away from the coils and coil sensitivity is not sufficiently independent to provide spatial encoding for InI. However, clear improvement of the spatial resolution was found by measuring InI at 7T than at 3T: areas with large aPSF values show much more reduced aPSF: quantitatively, with SNR = 0.1, the aPSF was 11.1 mm +/- 4.1 mm at 3T and 6.8 mm +/- 4.9 mm at 7T. With SNR = 1, the aPSF was 6.5 mm +/- 2.5 mm at 3T and 3.4 mm +/- 2.8 mm at 7T.

The figure below at right shows the spatial distributions of the reconstructed visual cortex activity at 3T and 7T in simulation with two active visual cortex areas (cyan). At SNR = 10, 7T reconstructions show more clear visual cortex activity at two discrete areas than 3T reconstructions. At SNR = 1, both 3T and 7T were difficult to distinguish these two areas.



DISCUSSION

In this study, we demonstrate that measuring InI at 7T has higher spatial resolution than at 3T. By using a coil array with the same 32 channels and a similar geometry, the spatial resolution quantified by aPSF can be improved about 65% and 90% at SNR = 0.1 and 1, respectively. Our calculations are encouraging for us to further validate this spatial resolution advantage by fMRI experiments. Considering the spatial distributions of aPSF, we expect that BOLD signal at visual cortex can be more accurately localized by 7T InI than 3T InI. This study used the MNE as the InI reconstruction method. We may further evaluate the spatial resolution with different reconstruction alternatives at 3T and 7T [3-5]. Lastly, it might be interesting to compare the potential spatial resolution improvement of using more channels in a head coil array at 3T, since a 7T system is less prevailing than a 3T system. While using more channels is expected to increase the spatial resolution, such improvement by adding more than 32 channels may be limited as suggested by electromagnetic analysis[6,7]. If so, measuring InI at 7T can be uniquely advantageous when high spatiotemporal resolution fMRI is required.

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