Magnetic Resonance Multi-view Inverse Imaging (MV InI) for Human Brain

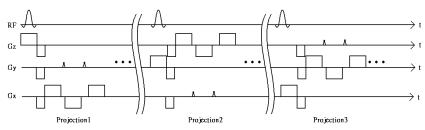**K. W-K. Tsai[1], T. Witzel[2], and F-H. Lin[1,3]**

[1]Institute of Biomedical Engineering, National Taiwan University, Taipei, Taiwan, [2]A. A. Martinos Center, [3]A. A. Martinos Center, Massachusetts General Hospital,

Charlestown, MA, United States

INTRODUCTION

Dynamic MRI usually uses echo-planar imaging (EPI) [1] to achieve high temporal resolution. In brain imaging, modern MRI systems can achieve 3D spatial encoding with the whole-brain coverage using multi-slice EPI with TR of 2 s. A significant amount of time of multi-slice EPI is spent over k-space traversal. Recently, we proposed the MR inverse imaging (InI) [2] to achieve the unprecedented temporal resolution (100ms) with whole-brain coverage using simultaneous acquisitions from channels of an RF coil array. InI traded off the spatial resolution for temporal resolution in solving ill-posed inverse problem. In this study, we propose the multi-view inverse imaging (MV InI) to achieve fast 3D MR imaging without compromised spatial resolution. Specifically, MV InI acquires projection data from three orthogonal directions (x-, y-, and z-axes) and all channels of an RF coil array.   All data are used simultaneously to solve the unknown 3D distribution of the magnetization. Here we present the pulse sequence and preliminary reconstruction of MV InI using a 32-channel head coil array at 3T to achieve 300 ms temporal resolution and 4 mm^3 isotropic spatial resolution.

METHODS

The figure at left shows the pulse sequence diagram of MV InI, which is based on the blipped EPI with volumetric spin excitation. Specifically, we alternate the coronal, axial, and saggital projection acquisitions repetitively to acquire the data using highly parallel detection. Before MV InI acquisitions, separate navigators in three projections were first acquired to correct the N/2 Nyquist ghost in each projection individually. In practice, the data were collected from a 3T MRI scanner (Tim Trio, SIEMENS Medical Solutions, Erlangen, Germany) with a 32-channel head RF coil array [3]. Before MV InI

acquisitions, we first separately acquired three reference scans, each of which was fully gradient encoded 3D multi-shot echo-volumar imaging. The parameters were: TR=100 ms, TE=30 ms, Flip angle=30°, image matrix=64x64, 64 partitions, FOV=256 mm x 256mm x 256 mm, bandwidth=2520 Hz/pixel). The MV InI acquisitions used the same 3D volumetric spin excitation and changed the partition encoding direction in consecutive acquisitions repetitively without any partition encoding steps using the same imaging parameters in the reference scan acquisitions.
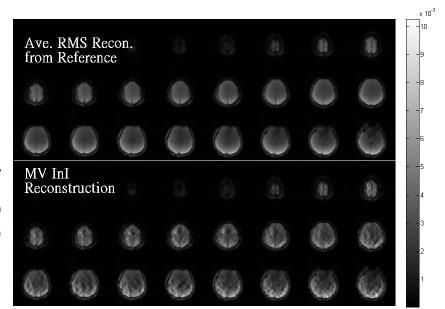
The reconstruction of MV InI data required three different projections. The reference scan with the partition encoding direction matched to each MV InI projection acquisition was used as the sensitivity map. We can thus construct a forward matrix $\mathbf{A}_{acc}$ consisting of data from all channels of the coil array and three reference scans. Mathematically, the 3D image to be reconstructed $\mathbf{x}$ and MV InI acquisitions $\mathbf{y}$ are related by a linear equation: $\mathbf{y}_{acc} = \mathbf{A}_{acc}\mathbf{x}$, This linear equation was solved by LSQR algorithm implanted in Matlab (Mathworks, Natick, MA, USA). The solution $\mathbf{x}$ was multiplied to the three reference scans to derive an average root-mean-square (RMS) across all channel images and three reference scan to generate final reconstructed 3D whole brain images. MV InI reconstruction changes the under-determined inverse problem of InI reconstruction into an over-determined inverse problem. Thus we can achieve an isotropic spatial resolution. Since three projections are required to estimate an 3D image, the effective TR for MV InI has a TR of 300 ms.

RESULTS

The figure at right shows 24 consecutive axial slices in the MV InI reconstructions from a single subject. For comparison, averaged RMS reconstruction from three reference scans was also shown. Qualitatively, both images are similar. Overall, the difference between the MV InI reconstructions and the reference scan has the maximal residual error of 0.49, after scaling the reconstructions linearly between zero and one.

DISCUSSION

Here we demonstrated the feasibility of achieving fast dynamic scan with whole-brain coverage using 3 shots MV InI with the temporal resolution of 300 ms. Importantly, this technology can offer isotropic spatial resolution. The penalty is the three times slower temporal resolution (300 ms) than our previous InI method, which is already about twenty times speedup compared to multi-slice EPI. Functional brain imaging using MV InI is under the way. This technology is sensitive to motion and image distortion since a good match between the accelerated projection scan and the reference scan is critical to ensure high image quality. This method can be also applied to motion correction in dynamic MRI scans.

REFERENCES

[1] Mansfield P. J. Phys. C., 1977. 10:L55–8.
[2] Lin, F.H., et al., Magn. Reson. Med., 2006. 56(4): p. 787-802.
[3] Wiggins, G.C., et al., Magn. Reson. Med., 2006. 56(1): p. 216-23.