Uniplanar MR Stage Microscopy: Proof-of-concept Imaging and Distortion Correction

L. Zhao[1], A. V. Demyanenko[1], Y. Kee[1], and J. M. Tyszka[1]
[1]Division of Biology, California Institute of Technology, Pasadena, CA, United States

Introduction: Magnetic resonance microscopy traditionally employs volume gradients and RF coils to maintain sensitivity at high spatial resolution in small samples[1]. Localized uniplanar gradient designs offer a higher gradient strength and faster slew rate than conventional cylindrical gradient sets[2]. These advantages can be exploited at high field to enable high spatiotemporal resolution imaging in living systems such as rapidly developing embryos. We describe initial imaging experience using a uniplanar MR stage microscope to acquire volumetric images of spatial calibration phantoms and biological samples. A distortion correction is also performed to compensate for intrinsic non-uniformities in the three-axis uniplanar gradient design.

Material and methods: All experiments were performed using a 7T horizontal bore magnet equipped with a conventional 40G/cm cylindrical gradient set and a Bruker Avance II console. The prototype uniplanar stage microscope was positioned within the conventional cylindrical gradient set, allowing sequential imaging using both gradient sets. The commercial gradient power supply was used to drive either the uniplanar gradient set or the cylindrical gradient set. A spatial calibration phantom was constructed consisting of a CNC drilled Ultem plate with 500 um diameter holes on a 650 um grid filled with aqueous 1 mM gadoteridol solution. All samples were mounted in a standard 35 mm Petri dish positioned over a 5 mm transceiver RF surface coil forming the upper surface of the stage microscope. Volumetric images were acquired using a 3D FLASH sequence. Effective spatial resolution at the center of the sample parallel to the gradient set was approximately 80 um. Gradient non-uniformity is an intrinsic element of uniplanar gradient designs and must be addressed if the resulting imaging data is to be used for quantitative morphological studies. Gradient non-uniformity corrections were based on the numerically modeled Bz field for each planar axis, accounting for estimated vertical offsets in the fabricated prototype. Numerical corrections were implemented in Matlab using fast cubic interpolation to unwarp distorted images. The effectiveness of the distortion correction was evaluated in volumetric images of uniformity phantom. Volumetric reference images, with presumed minimal spatial distortion were also acquired using the conventional cylindrical gradient set. Proof-of-concept images were also acquired of a set of fixed early and late neurula-stage frog embryos mounted in gadoteridol doped agarose.

Results and Discussion: Figure 1a shows a slice of the reference 3D images of the spatial calibration phantom acquired with the conventional cylindrical gradient set. Figure 1b shows the distorted image acquired with the uniplanar gradient set and the corrected image is shown in Fig. 1c. Interpolation artifacts are observed in the upper regions of the phantom, though these are well outside the designed region of uniformity of the uniplanar gradients. A slice of the distorted 3D images of frog embryos is shown in Fig. 2a and the corrected image is shown in Fig. 2b. Initial results are encouraging and suggest that, with appropriate thermostatic control of the sample medium, extended time-series imaging of millimeter scale organisms and tissue explants is entirely feasible with this hardware design.

Acknowledgments: The authors wish to thank Krish Subramaniam for assistance with Matlab coding. This work is supported in part by the National Science Foundation (NSF-0552396)

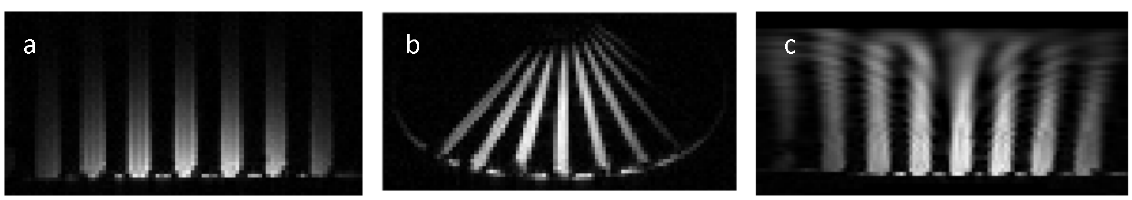

Fig. 1 (a) A slice of reference 3D images of the spatial calibration phantom acquired with the cylindrical gradient set. (b) The distorted image acquired with the stage uniplanar gradient set. (c) The unwarpped image interpolated from Image 1b.

References: (1) Tyszka, J. M.; Fraser, S. E.; Jacobs, R. E. *Curr Opin Biotechnol* **2005**, *16*, 93.
(2) Aksel, B.; Marinelli, L.; Collick, B. D.; Von Morze, C.; Bottomley, P. A.; Hardy, C. J. *Magn Reson Med* **2007**, *58*, 134.

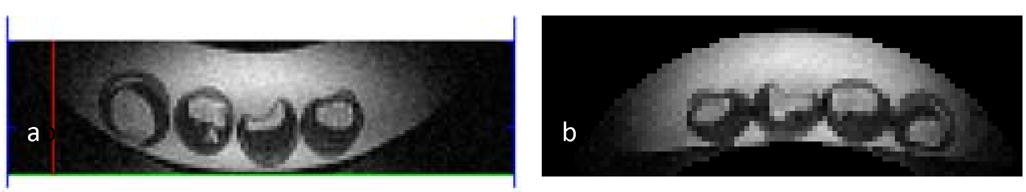

Fig.2 (a) A slice of the distorted 3D images of frog embryos. (b) The unwarpped image from Image 2a.