Magnetic Resonance Imaging

RLE Group
Magnetic Resonance Imaging Group

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Technical and Support Staff
Laura M. von Bosau

MRI Group Overview
The Magnetic Resonance Imaging (MRI) Group is new to RLE as of September 2004. Our research area is medical imaging with magnetic resonance, focusing on methods for acquisition, reconstruction and processing of *in vivo* imaging data. We have initiated three projects: (1) the development of efficient sampling and spatial encoding of spectroscopic magnetic resonance data; (2) estimation of brain metabolites in specific gray-matter regions for the study of migraine; and (3) investigation of ferrofluid nanoparticles as contrast and delivery agents in MRI.

The group consists of three EECS graduate students along with several collaborating faculty and students who are associated with MIT and with the HST Athinoula A. Martinos Center for Biomedical Imaging at Massachusetts General Hospital, (or, more briefly, the Martinos Center.)

The extensive resources of the Martinos Center, under the direction of Dr. Bruce Rosen and Dr. Greg Sorensen, are available to our group through collaborations with members in the Center. The Martinos Center is unique in the scope and variety of imaging equipment available, including four whole-body MRI scanners, one 3 Tesla (3T) head-only machine, and three high-field animal scanners. In the fall of 2005, the equipment options of the Martinos Center will be further extended by the addition of a whole-body, 3T human imager on MIT campus.

A number of sources support this multidisciplinary effort, including startup funds from HST and EECS; equipment and software training from Siemens Medical Solutions; equipment support from the Athinoula A. Martinos Center for Biomedical Imaging; National Institutes of Health (NIH) – National Center for Research Resources (NCRR) (Grant Number P41RR14075); the Mental Illness and Neuroscience Discovery (MIND) Institute. Collaborators on ferrofluid research received support from the Thomas and Gerd Perkins Chair held by Professor Mark Zahn; and generous alumnus Thomas F. Peterson.

1. Chemical Shift Imaging with Spiral-based k-space Trajectories (Spiral CSI)

Sponsors:
HST, EECS, NIH Grant Number P41RR14075

Project Staff:
Mr. Borjan Gagoski, Prof. Larry L. Wald, Prof. Elfar Adalsteinsson

A dominant limitation for chemical shift imaging (CSI) has been the encoding time required for phase encoding where at least one TR period is required for each resolved voxel. Thus, encoding a 3D volume of 16x16x16 voxels requires a minimum scan time of 16^3 = 4096 TR periods. However, by applying spiral-based readout trajectories, an equivalent volumetric sampling can be achieved in only 46 TR periods, which translates into an acceleration factor of 89 (16^3/46). Several attractive CSI applications become feasible with this dramatic speed up. In addition, the gradient encoding can be combined with parallel imaging to achieve further efficiencies in data acquisition.

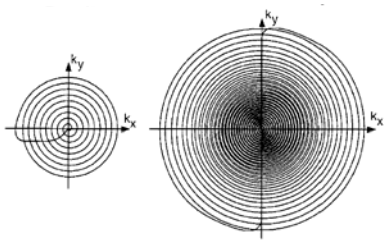

Figure 1 Spiral trajectories for non-weighted (left) and variable-density sampling designed to match a Hanning window. Voxel sizes are equivalent after the density-weighted acquisition has been windowed.

An example of the variety of data acquisition possibilities that open up with the flexible spiral-based sampling schemes is depicted in Fig 1. The two sampling schemes have identical voxel sizes but differently shaped spatial impulse response functions.

Our goal in this project is to develop a toolbox of spiral CSI methods combined with parallel imaging that can be applied to e.g. *i)* localized spectroscopic imaging of N-acetyl aspartate (NAA) and myo-Inositol in the hippocampal region for Alzheimer's disease; *ii)* whole-brain isotropic 3D choline, NAA, and lactate imaging for brain tumor imaging; and *iii)* a 5-minute, isotropic whole-brain NAA and lactate protocol to provide additional components for stroke outcome modeling by Dr. Sorensen.

2. Segmented Gray/White Matter Spectroscopy in Migraine

Sponsors:
HST, EECS, NIH Grant Number P41RR14075, NIH Grant Number 5P01NS 35611

Project Staff:
Ms. Karen J. Lee, Prof. Nouchine Hadjikhani, Prof. Larry L. Wald, Prof. Elfar Adalsteinsson

We recently initiated a collaborative project with Dr. Hadjikhani at MGH and HST to study the spectroscopic profile of gray-matter regions that were identified on cortical thickness maps as important to the study of migraine. We will use magnetic resonance spectroscopic imaging over the areas that show cortical thickness changes to determine whether these changes are due to a difference in the neuronal or glial population.

We will combine estimation of tissue compartments from segmented structural imaging with data from the much lower resolution spectroscopic imaging to derive gray matter and white matter spectroscopic markers of interest. The initial acquisition methods in this project rely on commercially available spectroscopic acquisitions on the Siemens platform, but as the Spiral CSI project develops, those methods will significantly enhance this project.

3. Applications of Ferrofluids in Magnetic Resonance Imaging

Sponsors:
HST, EECS, Thomas and Gerd Perkins Chair

Project Staff:
Mr. Kawin Setsompop, Mr. Xiaowei He, Prof. Markus Zahn, Prof. Larry L. Wald, Prof. Elfar Adalsteinsson

Exogenous contrast agents play an important role in biomedical imaging where they are used to enhance signal intensity or contrast against a noisy background, and more recently as labels in molecular imaging. In MRI, contrast agents are classified as either “positive” or “negative” based on their effect of increasing or decreasing the indigenous signal. Compounds in both categories are well studied and widely used, including commercial gadolinium-based agents for signal enhancement, (e.g. in MR angiography), or iron-oxide agents for cell labeling in animal models. In this project, we seek experimental verification of recent novel observations regarding the susceptibility of these agents, and have conducted preliminary imaging experiments to characterize our agents (Fig 2).

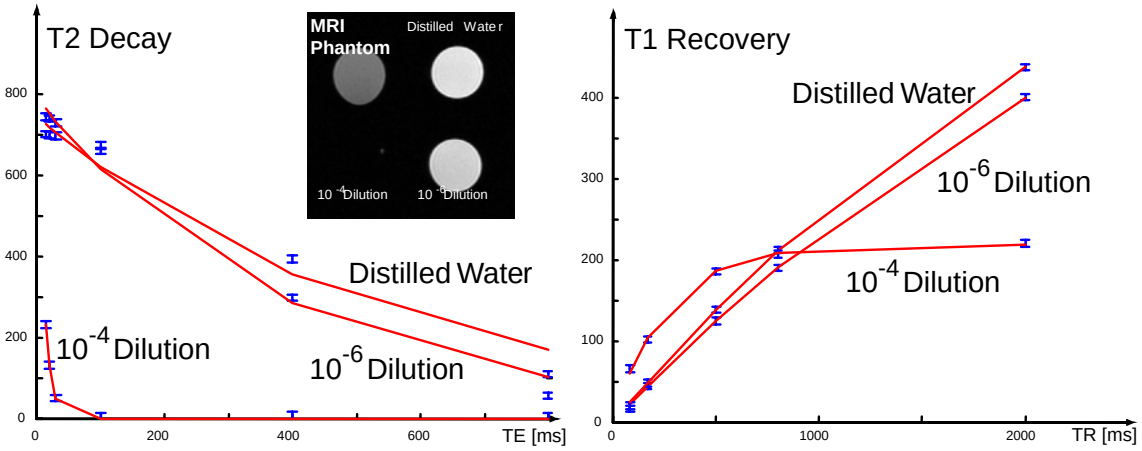

Figure 2. The **insert** shows the layout of vials in the MRI phantom constructed to evaluate the relaxation properties of diluted solutions of ferrofluid in water. The upper left quadrant has 10^{-2} dilution and by its signal void shows that the ferrofluid is a strong negative contrast T_2 agent. **Left:** Decay of MR-visible signal with increasing TE at TR=5s. The 10^{-4} solution clearly has a dramatically shorter T_2 than the distilled water and the 10^{-6} solution. **Right:** Signal recovery with increasing TR for TE=14ms with substantial shortening of T_1 for the 10^{-4} diluted ferrofluid.

Publications

Journal Articles, Published

E.V. Sullivan, H.J. Sable, W.N. Strother, D.P. Friedman, A. Davenport, H. Tillman-Smith, R.A. Kraft, C. Wyatt, K.T. Szeliga, N.C. Buchheimer, J.B. Daunais, E. Adalsteinsson, A. Pfefferbaum, K.A. Grant, "Neuroimaging of rodent and primate models of alcoholism: Initial reports from the Integrative Neuroscience Initiative on Alcoholism". *Alcoholism: Clinical and Experimental Research* 29:287-294 (2005).

Journal Articles, Accepted for Publication

A. Pfefferbaum, E. Adalsteinsson, E.V. Sullivan, "Frontal circuitry degradation marks healthy adult aging," *NeuroImage*, forthcoming.

A. Pfefferbaum, E. Adalsteinsson, E.V. Sullivan, "Cortical NAA deficits in HIV infection without dementia: influence of alcoholism comorbidity," *Neuropsychopharmacology*, forthcoming.

T. Schulte, E.V. Sullivan, E. Adalsteinsson, A. Pfefferbaum, "Corpus callosal microstructural integrity influences interhemispheric processing: a diffusion tensor imaging study," *Cerebral Cortex*, forthcoming.

A. Pfefferbaum, E. Adalsteinsson, E.V. Sullivan, "Dysmorphology and microstructural degradation of the corpus callosum: Interaction of age and alcoholism," *Neurobiology of Aging*, forthcoming.

C. Harper, I. Matsumoto, A. Pfefferbaum, E. Adalsteinsson, E.V. Sullivan, J. Lewohl, P. Dodd, M. Taylor, G. Fein, B. Landman, "The pathophysiology of 'brain shrinkage' in alcoholics structural and molecular changes and clinical implications," *Alcoholism: Clinical and Experimental Research*, forthcoming.

K. Crowley, E.V. Sullivan, E. Adalsteinsson, A. Pfefferbaum, I.M. Colrain, "Aging and delta wave production," *Sleep*, forthcoming.

Journal Articles, Submitted for Publication

A. Pfefferbaum, E. Adalsteinsson, E.V. Sullivan, "Supratentorial profile of white matter microstructural integrity in recovering alcoholic men and women," submitted to *Biological Psychiatry* (2005).

Meeting Papers, Published

D. Kim, E. Adalsteinsson, D. Spielman, "Reducing Gradient Imperfections for Spiral CSI," *Proceedings of the International Society for Magnetic Resonance* in Medicine, Miami, Florida, May 7-13, p. 722, 2005.

D. Mayer, M. Gu, D. Kim, E. Adalsteinsson, D. Spielman, "Effectively Decoupled Spiral CSI with Frequency-Selective Lipid Suppression at 3T," *Proceedings of the International Society for Magnetic Resonance in Medicine*, Miami, Florida, May 7-13, p. 726, 2005.

A. Pfefferbaum, E. Adalsteinsson, R.L. Bell, W.J. McBride, E.V. Sullivan, "An *in Vivo* Rat Model of Wernicke's Encephalopathy Imaged on a Human 3T Scanner," *Proceedings of the International Society for Magnetic Resonance in Medicine*, Miami, Florida, May 7-13, p. 1017, 2005.

E. Adalsteinsson, E.V. Sullivan, A. Pfefferbaum, “Proton MR Spectroscopy for *in Vivo* Quantification of Small Animal Brain Alcohol Kinetics,” *Proceedings of the International Society for Magnetic Resonance in Medicine*, Miami, Florida, May 7-13, p. 1038, 2005.

H. Yu, R. Fahrig, K. Butts, A. Ganguly, E. Adalsteinsson, D. Mayer, N.J. Pelc, “MR Imaging for Polymethylmethacralate During a Percutaneous Vertebroplasty Procedure,” *Proceedings of the International Society for Magnetic Resonance in Medicine*, Miami, Florida, May 7-13, p. 2150, 2005.

M. Gu, D. Kim, E. Adalsteinsson, D.M. Spielman, “Brain 3D MRSI Using Dualband Spectral-Spatial Excitation and K-Space Corrected Spiral Readout,” *Proceedings of the International Society for Magnetic Resonance in Medicine*, Miami, Florida, May 7-13, p. 2763, 2005.