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SY25-1

Accelerated MRI acquisition method with non-linear gradient fields

Sangwon Oh[1], R Todd Constable[1], Gigi Galiana[1], Dana Peters[1]

[1]Radiology and Biomedical Imaging, Yale University, New Haven, CT, United States, [2]Biosignals, KRISS, Daejeon, Korea

MRI with non-linear spatial encoding magnetic (SEM) field was originally introduced to make the most of faster gradient switching time without peripheral nerve stimulation (PNS) in 2008. Since then various MRI encoding schemes such as O-Space, 4D-Rio and FRONSAC have been introduced for more efficient accelerated spatial encoding. Unlike to conventional accelerated MRI acquisition schemes such as SENSE and GRAPPA which reconstruct with reduced or simulated k-space data, the non-linear SEM field methods make use of the increased high frequency information around at the edge of objects. Due to the non-uniform k-space, data reconstruction of non-linearly encoded data requires iterative methods. Even though the iteration methods take longer time compared to conventional FFT, the difference in reconstruction time can be reduced by using parallel computing in a case of 2-dimension (2D). However, it is questionable whether 3-dimensional (3D) non-linear schemes still have higher MRI acceleration compared to conventional methods and its reconstruction can be done in proper amount of time. Thus, we have investigated the applicability of non-linear SEM methods in 3D, especially O-Space and found the possibilities and limitations.

We implemented 3D O-Space by applying Z2 gradient on top of conventional 3D radial trajectory method, Koosh ball type. Constant Z2, $(z^2 - 0.5(x^2+y^2))$, gradient is turned on when linear gradients are applied. The amplitude of Z2 gradient is decided by locating a minimum gradient field position at the edge of an FOV. We have examined two iterative reconstruction methods, Kaczmarz and conjugated gradient (CG). Kaczmarz, very effective in the cases of 2D O-Space, has been found to be inefficient and inaccurate with 3D O-Space data. The slow convergence of Kaczmarz and gradient delay along z-direction are the source for the distorted 3D Kaczmarz reconstruction. However, CG successfully reconstructed the data with one big memory issue. The encoding matrix size, spatial coordinate of 128 x 128 x 32, 8 coils, 128 x 32 echoes and 128 data point, is 2 TB. We have addressed this issue by using coil-based reconstruction and generating the encoding matrix with an initial condition and a difference. Even though 3D O-Space shows marginally better image details compared to those in the radial method, the improvement over the radial method makes 3D O-Space impractical.

To justify additional gradient coil and increase in computation time we suggest an optimized Z2 gradient trajectory in k-space. Instead of using the conventional constant Z2 gradient as in O-Space, we oscillate Z2 gradient with a specific frequency and amplitude. From our simulation the optimized trajectory at high acceleration, R = 8, has comparable image quality of un-accelerated (R = 1) radial trajectory. Experimental implementation is under way and minimizing eddy current is one of the biggest issues. Extension to 3D can be done using stack of star type radial sequence instead of Koosh ball type.

Keywords : Non-linear gradient, Accelerated imaging, Reconstruction

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A New Ultrafast 3D Gradient-Echo Imaging Method: RASE

Jang-Yeon Park, Jae-Kyun Ryu

Biomedical Engineering, Center for Neuroscience Imaging Research, Sungkyunkwan University, Suwon, Korea

Ultrafast magnetic resonance imaging has been playing an important role in a variety of interesting preclinical/clinical applications such as diffusion imaging, perfusion imaging, cardiac imaging, functional brain mapping, and dynamic contrast-enhanced (DCE) imaging. Among ultrafast imaging techniques proposed, multi-slice 2D echo-planar imaging (EPI) methods have most widely been used in many applications. Despite their appealing features, however, EPI methods suffer from some drawbacks such as a blurring due to a relatively short effective transverse time (T_2^*/T_2), geometric distortion or signal loss in the presence of B_0 field inhomogeneity including large susceptibility difference, and Nyquist ghosting and chemical-shift effects along the phase-encoding direction due to a limited bandwidth available in practice.

Recently, alternative ultrafast imaging approaches have been developed using a non-conventional way of spatial encoding, called spatiotemporal encoding (SPEN), offering a good way of overcoming the EPI drawbacks. In SPEN-based imaging, a frequency-swept chirp pulse is used for sequential spin excitation producing quadratic phase distribution that can sequentially localize a signal in space and time around its vertex. Hence SPEN-based imaging needs no Fourier transform along the SPEN direction, thereby avoiding Nyquist ghosting and chemical-shift effects. Furthermore, it is relatively tolerant to the field-inhomogeneity by virtue of application of larger gradient amplitudes and an interesting property of the quadratic phase distribution that can partly recover signal loss induced by large susceptibility differences.

In this talk, a new ultrafast gradient-echo 3D imaging sequence will be proposed using SPEN, which is dubbed RASE (Rapid Acquisition with Sequential Excitation). The major differences of RASE from previous SPEN-based imaging methods are “3D gradient-echo-based” and “application of SPEN to the slab-selective direction”. RASE not only inherits the appealing features of SPEN-based imaging methods, but it can also reduce the effective TE by allowing the reduction of the field-of-view along the SPEN direction. Two types of RASE sequences will be introduced: In one version (RASE-I), spin excitation is performed with a chirp pulse of short duration (< ~1 ms), which allows a shorter effective TE due to the reduced excitation period. In the other version (RASE-II), spin excitation is performed with the same duration as data acquisition followed by a rephasing gradient, making all the spins experience the same constant echo time. RASE was demonstrated by phantom and in-vivo rat imaging on a 9.4-T animal scanner with the preliminary results of RASE-I and II in DCE-MRI and fMRI studies, respectively.

Keywords : 3D ultrafast imaging, Spatiotemporal encoding

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SY25-3

Blood-Brain Barrier Disruption using MR-guided Focused Ultrasound

Juyoung Park

Medical Device Development Center, Daegu-Gyeongbuk Medical Innovation Foundation, Daegu, Korea

During the last years, the knowledge of ultrasound non-invasively induced bio-effects significantly changed the scope of how ultrasound might be used in the future. Non-invasive and targeted brain surgery using MR image-guided focused ultrasound (MRgFUS) became major research developments in the field of therapeutic ultrasound. In addition, temporary blood-brain barrier disruption (BBBD), local drug delivery and the controlled induction of cell modulations are major topics of current therapeutic ultrasound research activities. The MRI-guided focused ultrasound system broadened the variety of potential brain applications significantly, including brain tumor, stroke, neurodegenerative diseases and neuromodulation etc. This presentation will give an overview of blood-brain barrier disruption and targeted drug delivery into the brain using MR-guided focused ultrasound.

Keywords : Blood brain barrier, Focused ultrasound, Dynamic contrast enhanced imaging, Drug delivery

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SY25-4

Quantitative MR imaging of microvasculature

HyungJoon Cho

Biomedical Engineering, UNIST, Ulsan, Korea

Our lab focuses on developing and applying in vivo MR methods to quantitatively

visualize microvasculatures using small animal model. In this talk, we will present our recent developments in MR micro-angiography and direct evaluation of blood brain barrier integrity with multiple contrast agents.

Keywords : -