B_0 anchored spatial excitation for spectroscopic imaging under field inhomogeneity

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Introduction

Spectroscopic imaging (SI) has been in constant development for the past two decades. While the unique ability of SI to evaluate specific brain metabolites and their spatial distribution has made it appear to be the ideal technique to assess brain function more directly than other techniques, challenges exist in fully realizing its potential in translational applications - chief among them may be its vulnerability toward B_0 field inhomogeneity. In order to achieve metabolite-specific excitation over a large volume (i.e. human brain), a highly uniform magnetic field across the brain is required. Although the magnet technology has allowed large volume uniformity in homogeneous samples, the various tissue types, in addition to air spaces and bone structures, in human brains make it especially challenging to achieve B_0 homogeneity and effective SI. As such, while SI has great potentials for metabolite imaging across the brain, it is often challenging to obtain accurate maps of metabolites in vivo.

Methods

Many techniques have been developed to better shim the magnetic field, in an effort to improve the magnetic field inhomogeneity [1,2,3]. In light of recent progress in parallel transmission [4,5], we propose here a new strategy that allows individual transmit channels to broadcast RF pulses with their frequencies matched to the immediately adjacent regions. This strategy effectively anchors the excitation frequency to match the B_0 profile in space.

To test this new concept, experiments were conducted in a solution phantom containing similar metabolites as those in the brain, including creatine, choline, NAA, and lactate. Single-voxel spectrum and chemical shift images were acquired to evaluate the effectiveness of the Bo anchored spatial excitation (BASE) strategy. Three sessions were conducted: 1) spectra were acquired under a homogeneous magnetic field, with r.m.s frequency deviation across the 20 cm DSV less than 20 Hz; 2) spectra were acquired under an inhomogeneous field with magnetic field variation at 6 Hz/mm across the phantom – this field gradient was superimposed to simulate the magnetic field gradient in vivo near air/tissue/bone interfaces; 3) spectra were again acquired under the same inhomogeneous field, but with a frequency-matched excitation at the local region. All experiments are performed on a 4T whole-body MRI scanner (GE Healthcare).

Results

Shown in Fig. 1 are MR spectra under the various experimental conditions. Under a homogeneous magnetic field, the spectrum depicts the various metabolic peaks as shown in Fig. 1A. However, the magnetic field gradient used in session 2, while not altering the resonance frequency in the center, greatly shifted the resonance frequency at the perimeter of the phantom. In a normal single-coil transmission scenario, the excitation frequency would not be able to accommodate the frequency shift and dispersion, and would remain at the original value. As a result, the MR spectrum at the perimeter of the phantom will suffer from the large off-resonance effect as well as significant linewidth broadening. These artifacts are illustrated in Fig. 1B. Using a BASE scheme that would allow individual transmit channels to match the frequencies of the immediately adjacent local regions, the effectiveness of spin excitation and spectral accuracy is restored, as shown in Fig.1c.

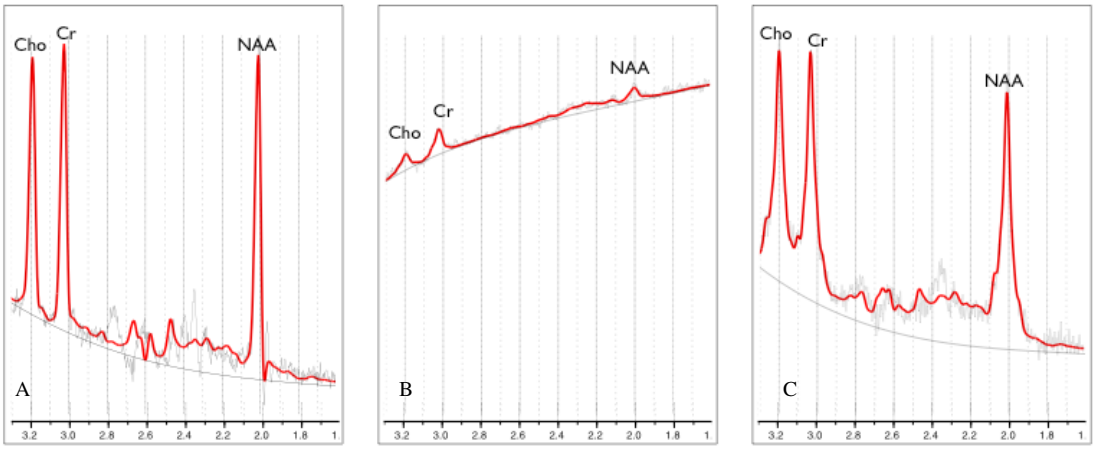

Figure 1 A- Spectrum showing Choline, Creatine and NAA peaks under homogeneous magnetic field conditions; **B-** Same spectrum afer superposition of a heterogeneous field; **C-** Restored spectral resolution under same inhomogeneous conditions using B_0 anchored spatial excitation.

Discussion

Here in this report we demonstrate a new excitation concept, enabled by the recent progress in parallel transmission, that can allow the region-specific transmit frequencies to be broadcast from the individual channels. The continued advances in parallel transmission hardware, e.g. the increase of the number of transmit coils, will be able to address the multiple resonance frequencies within the volume under an inhomogeneous magnetic field, such as that seen in human experiments. We anticipate that this new excitation strategy will find broad applications leading to more effective whole-brain spectroscopic imaging in vivo.

References

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