Acquisition-weighted Ultrashort TE Chemical Shift Imaging (aw UTE-CSI)

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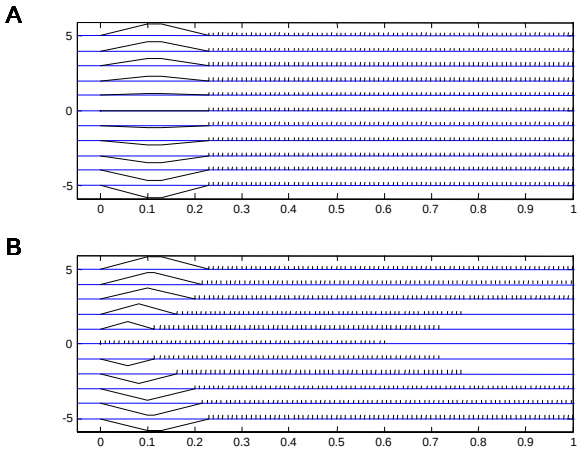
Introduction

In addition to the long T_2 components that can be observed in MRI there also exist tissues that have short T_2 components. The short T_2 components have been shown to provide novel or complementary information in a number of disease states [1]. The existing methods used for short T_2 imaging allow the sequence to be optimised for a single T_2, but when the sample contains multiple T_2 components the sequence is compromised. For example a low readout bandwidth will yield high SNR for the long T_2 components, but blurring and low signal from short T_2 species; whereas the choice of a high readout bandwidth will yield good quality images of the short T_2 species, but long T_2 species will not be sampled efficiently and signal in those species will be lost. Multiply phase-encoded Fourier transform chemical shift imaging (CSI) methods yield spectral information for long T_2 components and also allow us to examine the contribution of long and short T_2 components in each voxel [2]. The CSI approaches, therefore, do not suffer from this compromise.

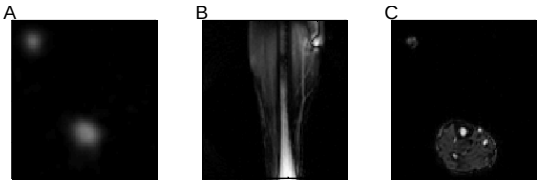


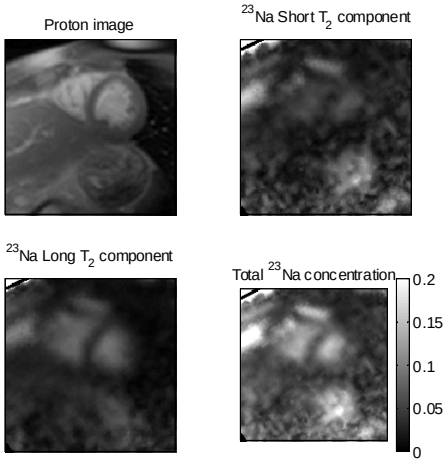
In order to optimise this method to all T_2 species (including those with very short T_2) we have devised methods of minimising the effects of T_2 relaxation, and this Ultra Short TE CSI (UTE-CSI) method is described. In conventional CSI the phase-encoding gradients are of constant duration but variable amplitude (1A above right). In the UTE-CSI described here an alternative approach is taken in which in addition to minimising the time for the RF excitation we also minimise the time delay (T_d) prior to acquisition for each point in k-space individually (1B above right). This results in very short T_d (70μs) at the centre of k-space and longer T_d at the periphery of k-space. On the clinical machine used this results in an effective delay of 70μs and an echo time (TE) from the centre of the excitation pulse of 170μs to the centre of k-space versus 1-2ms for the conventional CSI method. The benefit of this method is that there is much less decay of the signal before acquisition, which allows us to image species with very short T_2 (e.g. 200μs) and improves the images of species with intermediate T_2 yielding an increased signal to noise ratio.

Methods & Results

The UTE-CSI sequence was implemented within IDEA on a 1.5T Siemens Sonata MR system. This included cardiac gating, a variable matrix size (8-64 in any direction), acquisition weighting, and preparation pulses. Processing was performed using programs written in Matlab. In the cases shown here there is a single frequency and so linear phase correction was un-necessary (if necessary this step is performed on each k-space line separately prior to Fourier transformation to correct for the differential time delays within the acquisition). Excitation used a 200μs square pulse with no slice selection gradient, and the image FOV was limited by the coil Rx profile. The ^{23}Na (Rapid Biomedical) and ^{31}P (Siemens) rf coils use a large Tx coil and small quadrature Rx coil.

We demonstrate the applicability of this approach for imaging the short T_2 phosphorus signal in cortical bone (see right, A=axial ^{31}P, B=trans ^{1}H, C=axial ^{1}H). The human tibia has been imaged in 3D in 9min. 30s, and from the acquired data we can create images, and determine the T_2* (here 189μs which is consistent with previous work [3]).





Results are also shown from Sodium in the human myocardium. In this case the sodium has short and long T_2 components [4]. Using the spectral data we can extract these relaxation rates, and determine concentrations of the two components. As the delay time is short (170μs) we lose very little signal due to relaxation from the short T_2 component. In this work we have corrected for the reception profile of the RF coil and can reference the sodium concentration to the known sodium concentration in the blood pool. The images (see left) show the different components and the total sodium concentration for a single slice of a 3D set acquired in 22minutes on a normal volunteer at 5x5x15mm resolution. It should be noted that the point spread function of the short T_2 component is not degraded significantly by relaxation, this may be in contrast to sequences using centre-out k-space trajectories that attempt to optimise the signal to noise for both the short and long T_2 components. Short T_2 components from the cartilage are resolved clearly.

Conclusion

It is possible to create a CSI-based method that is sensitive to species with ultra-short T_2s (here below 200μs). This approach is efficient compared to existing acquisition methods and is demonstrated here to have a number of different applications.

References: 1) Robson MD. et al. JCAT 2003. 2) Brown TR. et al. Proc. Natl. Acad. Sci. USA 79, 3523 (1982). 3) Robson MD. ISMRM 2003 #718. 4) Constantinides CD et al. MRM 46:1144(2001).