Ultra-short Echo Time Difference (USTED) Data Acquisition for T2* Contrast Reversal

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ABSTRACT

MR cell tracking studies capitalize on the strong B0 inhomogeneity defect produced by small paramagnetic particles (SPA). Recent studies have demonstrated the sensitivity of such approaches for detecting cell migration during organ transplant and stem cell implantation (1). Although the contrast mechanism that SPA-based approaches rely on is very effective, the signal loss due to the large field inhomogeneity could sometimes limit the usefulness of the technique. In this work we present a theoretical and experimental demonstration of the use of dual-echo, ultra-short echo time difference (USTED) data acquisitions for improving the usefulness of T_2*-weighted scans in cell tracking studies.

METHODS

Basic Approach: The underlying motivation for the proposed approach is that intra-voxel dephasing, the dominant contrast mechanism in SPA-based cell tracking studies, is negligible for ultra-short (<400μs) echo times. Consequently, if an ultra-short echo time data set is acquired concurrently (during the same imaging session) as the T_2*-weighted image commonly used for identifying the location of SPA's in the field of view (FOV), the difference between these two images will only be non-negligible at the SPA's sites and will exhibit a signal intensity that follows the behavior shown in Figure 2. Hence, the negative contrast commonly attributed to this contrast mechanism can be reversed while at the same time removing most of the image interpretation confounds associated with this form of T_2* contrast mechanism.

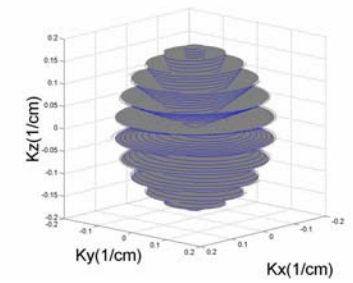

Figure 1: *k-space depiction of the TPI data acquisition scheme.*

Computer Simulations: Computer simulated data sets were used to demonstrate the proposed approach. A twisted projection imaging (TPI, Figure 1) data acquisition scheme (2), which is capable of ultra-short echo times, was used to generate data sets with TE=0 and 10ms for a simulated object consisting of two cylindrical vials with the same spin density but vastly different T_2* (2ms and 6000ms, respectively). All data were generated in k-space through direct evaluation of the analytical 3D Fourier transform for the object followed by sampling along the TPI trajectory. Images were reconstructed using a 3D gridding algorithm described previously.

Experimental Studies: Experimental data sets were acquired on a 3T whole body clinical scanner (GE Health Care, Milwaukee, WI) using a custom-built, dual-tuned, dual-quadrature, 5cm diameter, birdcage coil (3). The acquisition parameters for the experimental data sets (number of excitations, and spatial resolution) were chosen to mimic those used in the computer simulations except for the shortest echo time, which was limited to 400μs. All images were reconstructed off-line using the same algorithm as in the computer simulations.

RESULTS

The effectiveness of the proposed approach is demonstrated in Figure 3a where the computer simulated results for the two-vial experiment are presented. The images correspond to TE=0 (left), TE=10ms (center) and their difference (right). Only one slice from the 3D data set is shown. The short T_2* object corresponds to the rightmost disk. This disk has negligible signal in the long echo time image (center) but is clearly recovered in the difference image shown on the right. The same findings demonstrated in the simulated object are also present in the experimental data set shown in Figure 3b. The imaged object corresponds to seven test tubes with gel suspensions containing Feridex-loaded and unloaded cells of different concentrations. The corresponding values are as follows (starting at the 1 o'clock position and continuing clockwise), 10^4 cells no Feridex, no cells no Feridex, 10^4 cells Feridex, 10^6 cells Feridex, 10^6 cells no Feridex, 10^4 cells no Feridex, 10^5 cells Feridex. The tube with the largest density of SPA's corresponds to the lowesmost disk. This tube, as expected, has negligible signal intensity in the TE=10ms image but it is clearly visible in the difference image. Conversely, the control tubes have negligible signal intensity in the difference image. As in the computer simulated data set, the images correspond to TE=400μs (left), TE=10ms and their difference (right). Only one slice from the entire 3D data set is shown. The image on the left in Figure 4, clearly demonstrates the contrast reversal anticipated with the use of the proposed technique.

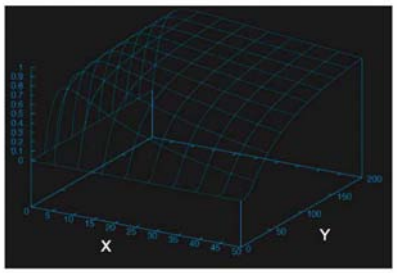

Figure 2: *Expected signal intensity for USTED data acquisitions as a function of the longest echo time (x-axis, ms) and T_2* difference (y-axis, ms).*

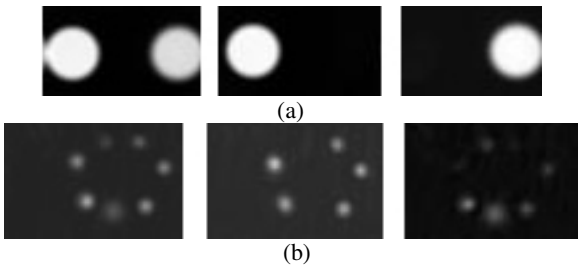

Figure 3: (a) *Selected partitions from computer simulations of a two vial phantom with vastly different T2* (2 and 6000ms for the right and left objects). The leftmost image was generated for TE=0ms while the one the center corresponds to TE=10ms. The rightmost image is the difference between the two.* ***(b)*** *Selected partitions from experimental data sets from a 7 tube phantom. The leftmost image was acquired with TE=0.4ms while the one the center corresponds to TE=8ms. The rightmost image is the difference between the two.*

CONCLUSIONS

We have demonstrated the use of dual-echo, USTED acquisitions for contrast reversal in heavily T_2* weighted experiments. Because the underlying data acquisition schemes are fast, the proposed technique could be of great benefit for monitoring cell trafficking during transplant and stem cell implantation experiments using MRI.

REFERENCES

[1] Ho, C. et al., Curr. Pharm. Biotech, **5**, 551, 2004. [2] Boada, F.E. et al., Magn. Res. Med., **37**, 706, 1997. [3] Shen, G. et al., Magn Res Med, **38**, 717, 1997.

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