A Novel Sequence to Improve Signal to Noise in DCE Measurements

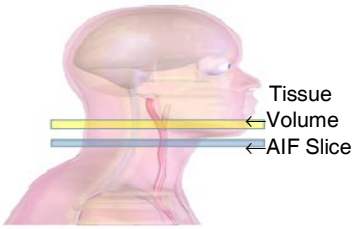
Jason Kraig Mendes[1], Scott McNally[2], and Dennis L Parker[1]

[1]*Radiology, University of Utah, Salt Lake City, Utah, United States,* [2]*Clinical Radiology, University of Utah, Salt Lake City, Utah, United States*

Target Audience: Clinicians/Researchers using dynamic contrast enhanced imaging to evaluate vascular systems.

Purpose: Dynamic contrast enhanced (DCE) imaging is useful in evaluating the functional status of a vascular system (1). While the distribution of a contrast agent into a tissue is a function of pathology and contrast agent pharmacokinetic properties, the measured signal changes in MRI are due to the relaxivities of the contrast agent (2). After contrast agent injection, MR images acquired with a T_1 or T_2 weighting can be compared to a baseline images to determine changes in tissue relaxation and calculate contrast agent concentration in the blood supply (arterial input function or AIF) and in the tissue (3). For DCE MRI a high spatial resolution (especially in the tissue) would be valuable in detecting small changes in vascularity while a high temporal resolution (especially for the AIF) would lead to more accurate kinetic parameter calculation (4,5). Hybrid sequences have addressed this by interleaving a high temporal acquisition for the AIF with a high spatial resolution volume for the tissue (6) but the resulting high temporal and spatial resolutions result in poor signal to noise characteristics of the data. This can be improved since currently DCE imaging methods rely on either T_1 or T_2 weighted images to measure contrast agent concentration. We propose a novel sequence (Dual Dynamic Contrast Enhanced or DDCE) which combines the high temporal and spatial resolution desired from the hybrid sequences but acquires both T_1 and T_2 weighted images to simultaneously measure concentration agent concentration based on T_1 or T_2 analysis. The two measures of concentration can then be averaged to improve signal to noise. In addition, some applications benefit from injection of two different contrast agents (often one diffusive and the other a blood pool or susceptibility weighted agent) (7). These protocols require long periods of time between injections to allow the first contrast agent to clear or require multiple injectors and complex modeling to account for residual contrast agent concentrations between injections. In these cases, the T_1 and T_2 weighted images from the proposed sequence could be used to quantify the ratio of each contrast agent in a given tissue or blood voxel. Phantom data is presented measurements

Methods: A high temporal resolution 2D slice was interleaved with the acquisition of a high spatial resolution 3D volume (Fig. 1). The 2D slice was acquired in close spatial proximity to the 3D volume which allowed blood contrast concentration to be determined from the 2D images while tissue contrast concentrations were determined from the 3D images. The sequence consists of a non-selective saturation block and two segmented EPI blocks. Each segmented EPI block acquires multiple lines of the data followed by a refocusing RF pulse and then acquisition of the same data lines The first set of acquired lines form the T_1 weighted image while those acquired after the refocus pulse form the T_2 weighted image. For a single contrast agent the concentration can be found from both the T_1 and T_2 weighted data as:



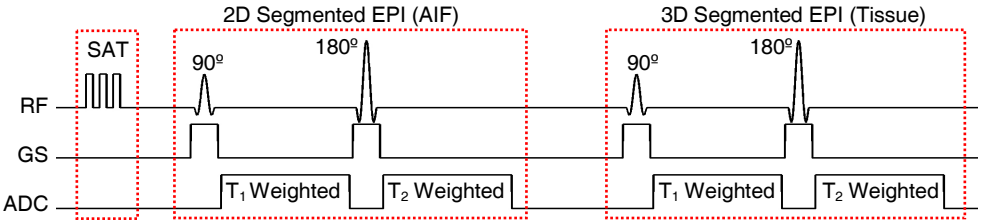
(a)

$$\frac{1}{T_1} = \frac{1}{T_{1(0)}} + r_1 \cdot C \qquad \frac{1}{T_2} = \frac{1}{T_{2(0)}} + r_2 \cdot C$$

while the concentrations from a dual injection can be found as:

$$\begin{bmatrix} \frac{1}{T_1} - \frac{1}{T_{1(0)}} \\ \frac{1}{T_2} - \frac{1}{T_{2(0)}} \end{bmatrix} = \begin{bmatrix} r_1^A & r_1^B \\ r_2^A & r_2^B \end{bmatrix} \begin{bmatrix} C_A \\ C_B \end{bmatrix}$$

where r_1 and r_2 are the longitudinal and transverse relaxation constants for contrast agents A and B, T_1 and $T_{1(0)}$ are the measured and equilibrium T1 relaxation times, T_2 and $T_{2(0)}$ are the measured and baseline transverse relaxation times and C_A and C_B are the concentrations of each contrast agent in the given voxel.



(b)

Figure 1: Location of data acquired for the 2D arterial input function and the 3D tissue volume are shown in (a). The AIF slice is positioned below to help saturate blood signal in the tissue volume. The sequence diagram used to acquire both T1 and T2 weighted images for both the 2D AIF and 3D tissue volume is shown in (b).

Results: R_2 measurements made using the DDCE sequence were compared to a turbo spin echo and a spin echo sequence as shown in Figure 2. Multihance contrast agent was injected into a water flow phantom using a power injector with the corresponding concentration curves shown in Figure 3.

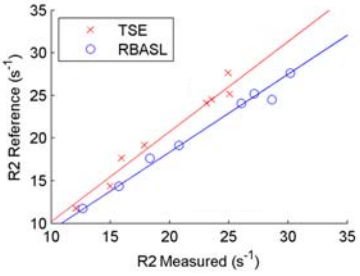


Figure2: Validation of R_2 in a phantom with various R_2 rates. The R_2 maps were obtained from a spin echo, turbo spin echo and DDCE sequence. The values from the spin echo sequence were taken as the reference.

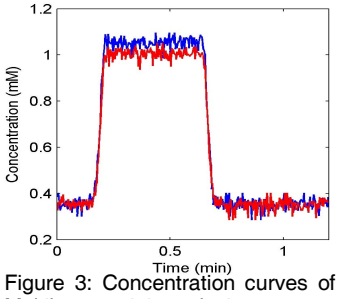


Figure 3: Concentration curves of Multihance injected into water calculated from T_1 (blue line) and T_2 (red line).

Discussion: Comparing the R_2 values measured in Figure 2, the DDCE sequence is shown to make good measurements of R2 compared with a conventional spin echo sequence. Although the concentration curve derived from T_2 had lower peak values when compared to the curve derived from T_1 they are in reasonable agreement.

Conclusion: A new DCE sequence that measures both T_1 and T_2 has been shown to be feasible.

Acknowledgments: This work was supported with resources from the George E. Wahlen Department of Veterans Affairs Medical Center (Salt Lake City, Utah) as well as funding from Ben B. and Iris M. Margolis Foundation, Cumming Foundation, Mark H. Huntsman Endowed Chair and Siemens Medical Solutions.

References: 1) O'Connor et al. 2011;84:S112–S120. 2) Rohrer et al. Invest Radiol 2005;40:715–724. 3) Tofts et al. paul-tofts-phd.org.uk. 4) Parker et al. Magn Reson Med 2006;56:993-1000. 5) Gaens et al. Radiology 2013;266:271-279. 6) Mendes et al. 7) Pedersen et al. J. Biomedical Science and Engineering 2011;4:315-319.