Improving Multi-exponential T2 Measurements

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Introduction:

A non-invasive method of accurately quantifying myelin content would be useful in basic science as well as the clinic. Neural tissue has been shown to exhibit multi-exponential T_2 decay (MET_2) which can be imaged using a multi-echo sequence (1). However, accurate measurements of myelin T_2 are severely hampered by its rapidly decaying signal. One solution lies within the properties of the myelin. The irreversible rate of relaxation (R_2) of myelin water is significantly larger than the typical macroscopic reversible rate of relaxation (R_2'). We previously showed that shifting the sampling of $\boldsymbol{k} = 0$ to times earlier that TE improves metrics of short-T_2 component imaging (2). In practice, such a shift can be achieved using a modified RATE sequence (3) with a spiral trajectory (see value Φ in Fig 1). In addition to acquisition shifting, acquiring signal between the 90 and first 180 pulses, what we will call the *zeroth* echo, will also improve our overall SNR (Fig1).

In order to align zeroth echo data with the subsequent spin-echoes, two factors must be considered: 1) the effect of R_2' on the zeroth echo and, 2) the effect of imperfect refocusing on the subsequent echoes. That is,

$$M(\varphi) = M_0 \exp\left(-\varphi\left[R_2 + R_2'\right]\right), \text{ and}$$

$$M(nTE) = M_0 \exp\left(-nTE\left[R_2 + R_2^{RF}\right]\right)\exp\left(\Phi\left(R_2 + R_2^{RF} - R_2'\right)\right),$$

where R_2^{RF} depends on the RF refocusing efficiency and the inter-echo time (4). Given the assumption that both of these factors are constant over the size of an imaging voxel, corrections to the echo magnitudes acquired using the pulse sequence in Fig 1 can be made based on one additional measurement. Specifically, the GESFIDE imaging sequence can measure both R_2' and R_2 independent of RF flip angles (5), which is sufficient information to correct all echoes acquired with the spiral-RATE sequence.

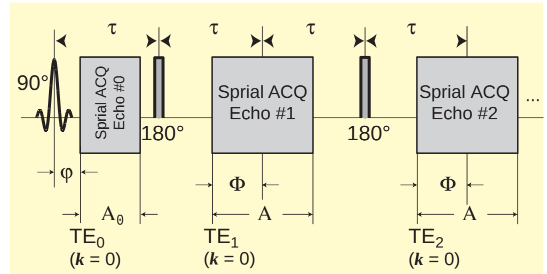

Fig 1. Acquisition period timings for inclusion of the zeroth echo into the spiral-RATE pulse sequence. The parameter Φ indicated shift in time of the $k = 0$ sampling. In addition, the parameter φ defines the delay between excitation and the sampling at $k = 0$ of the zeroth echo.

Methods and Results:

A standard single slice multi-echo sequence was modified to include the aforementioned zeroth echo, but without the echo shifting (i.e., $\Phi = 0$). Using an $MnCl_2$-doped water phantom (Fig 2) this sequence was used to collect 17 echo images with a 64 x 64 data matrix, a 60 mm FOV and timing parameters φ/TE/TI = 1.014ms /8ms /2sec. The GESFIDE sequence was also used with the same imaging geometry, 8 echoes with the fist echo acquired at 2ms and with an inter-echo time of 1.5ms for falling and rising signal phases. From these images, R_2 and R_2' maps were computed and subsequently used to correct all 17 images collected using the spiral-RATE sequence with zeroth echo. Figure 3 shows the adjusted zeroth echo points (represented as red circles) on the corrected R_2 curves.

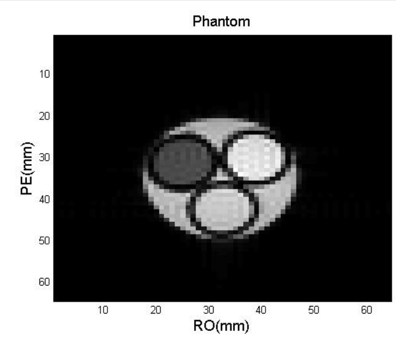

Fig 2. Phantom. 64x64 data matrix, 60mm FOV. R_2 of A = $77s^{-1}$, R_2 of B = $10s^{-1}$, R_2 of C = $20s^{-1}$

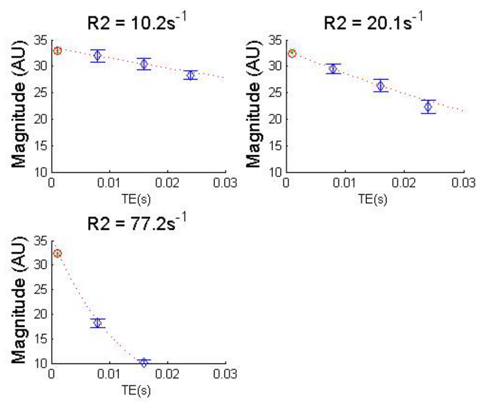

Fig 3. Blue diamonds indicate the calculated data and the dotted red line is the calculated line fit. The red circle represents the adjusted zeroth echo. Zeroth echo onset (φ) was 1.014ms.

References

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The authors would like to acknowledge financial support from the NIH,
Grant #EB001744.