**Title:** Improving the specificity of $R_2^\prime$ to mesoscopic magnetic field inhomogeneity by compensating for through-slice magnetic field gradients during image acquisition.

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**Abstract:**

**Target Audience:** Researchers interested in using $R_2^\prime$ measurements for quantification of iron concentration and oxygen metabolism.

**Purpose:** The reversible transverse relaxation rate, $R_2^\prime$, is sensitive to mesoscopic magnetic field inhomogeneity resulting from subvoxel differences in magnetic susceptibility. This sensitivity has been exploited to measure tissue iron concentration, resting oxygen extraction fraction and changes in oxygen metabolism. However, $R_2^\prime$ is also sensitive to macroscopic magnetic field inhomogeneity that left uncorrected will reduce the specificity of these applications. In this work we implemented a method to compensate for the through-slice component of the macroscopic effect during image acquisition.

**Background:** $R_2^\prime$ is most commonly measured using the GESSE, GESPIDE and ASE pulse sequences. The effect of macroscopic magnetic field inhomogeneity is usually corrected via post-processing in combination with a separately acquired magnetic field map. The GESSE/GESPIDE methods produce images with simultaneously varying $R_2^\prime$ weighting with constant $R_2^\prime$ weighting, whilst the ASE method is able to manipulate $R_2^\prime$ weighting with constant $R_2^\prime$ weighting. This enables $R_2^\prime$ to be fitted directly rather than requiring the removal of the $R_2$ effect prior to fitting for $R_2^\prime$, as is the case with GESSE/GESPIDE. Compensation for field gradients in the slice dimension (z-gradients) using the Gradient Echo Slice Excitation Profile Imaging (GESEPI) method has previously been used for $R_2^\prime$ mapping. Here we utilise this technique for mapping $R_2^\prime$ at 3T.

**Methods:** An EPI ASE sequence was implemented as a baseline comparison. Imaging parameters were FOV 240mm, 64x64 matrix, twenty 5mm slices, TR 3s, BW 2004Hz/px. Raw data were Hanning filtered prior to reconstruction. Images were acquired with six different levels of $R_2^\prime$ weighting: $\tau$=15, 18, 21, 24, 27, 30ms. A GESEPI ASE acquisition was implemented by phase encoding each 5mm slice in the z dimension. In effect each 5mm slice was split into four 1.25mm subslices and acquired with 100% partition oversampling to reduce aliasing (total 8 k-space partitions). The four reconstructed subslices were then summed to produce a single 5mm slice. Images were acquired in 3 subjects with each sequence matched for scan duration (2min 24s): 8 averages for EPI ASE, 1 average for GESEPI ASE. Images were smoothed with a 2mm kernel and $R_2^\prime$ was mapped using a 2 parameter fit to the following model: $S=S_0 e^{-\tau R_2^\prime}$.

**Results:** Fig. 1 presents a subset of 4 slices from $R_2^\prime$ maps generated by EPI ASE and GESEPI ASE. The effect of the z-gradient is visibly reduced in GESEPI ASE. Notably the $R_2^\prime$ of slice 12, which is superior to the nasal sinus, is reduced to be in line with neighbouring voxels. The effect of the z-gradient persists in slice 16 of the EPI ASE images, but is corrected in GESEPI ASE. Finally signal is recovered in slice 10 where the z-gradient is largest, but residual $R_2^\prime$ elevation remains. This pattern is consistent with measured in-plane magnetic field gradients (not shown). Fig. 2ab display histograms of cortical grey matter $R_2^\prime$: Whilst the mode value of $R_2^\prime$ in both methods (3.0s⁻¹) was identical, the spread of values is reduced in GESEPI ASE. Fig. 2c suggests that this is due to effective correction of large EPI ASE $R_2^\prime$ values without overcorrecting voxels unaffected by z-gradients.

**Discussion:** The GESEPI ASE method enables direct measurement of $R_2^\prime$ with compensation for z-gradients, caused by macroscopic magnetic field inhomogeneity, which is effective in most of the brain. This is achieved in a short scan duration and does not require $R_2$ to be fitted, removing potential sensitivity to multicomponent $R_2$ decay. Larger z-gradients can be compensated by increasing the number of subslices acquired, but will result in longer scan times. Further work is required to compensate for in-plane gradients, potentially using postprocessing techniques.

**References:**