Including a Third, Non-Exchanging Water Component in mcDESPOT
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INTRODUCTION: Assessment of myelin content through multi-component analysis of relaxation data (MCR) provides salient information in de-myelinating disease (such as multiple sclerosis), as well as neurological disorders arising from altered brain connectivity. T2-based MCR analysis [1] consistently reveals at least 2 water compartments in brain parenchyma, attributed to water between the myelin bilayers; and intra/extra-axonal (IE) water [2]. A third pool, bulk free water (e.g., cerebral spinal fluid, CSF) may also be present [2]. Multi-component Driven Equilibrium Single Pulse Observation of T1 & T2 (mcDESPOT) [3] is an alternative MRC method that, unfortunately, assumes only two water pools. While informative, this model may fail in partial volume voxels, leading to a biased MWF estimate. Inclusion of a third, non-exchanging component to the mcDESPOT model may correct for these effects. (Fig. 1). Here we outline the mathematical framework and investigate results from a healthy adult and an elderly patient with Alzheimer’s Disease (AD).

METHODS: The three-component SPGR and bSSFP magnetizations are given by:

\[
M_{\text{SPGR}} = M_{\text{SPGR}}(I - e^{-\alpha_{\text{SPGR}} R(\alpha) T_{\text{R}}}) \sin \alpha \times (I - e^{-\alpha_{\text{SPGR}} R(\alpha) T_{\text{R}}}) \cos \alpha)^{-1}
\]

\[
M_{\text{bSSFP}} = (e^{-\alpha_{\text{bSSFP}} R(\alpha) T_{\text{R}}}) A_{\text{bSSFP}} C \times [I - e^{-\alpha_{\text{bSSFP}} R(\alpha) T_{\text{R}}}]^{-1}
\]

where \(I\) is the 3x3 or 9x9 identity matrix, \(M_{\text{SPGR}}, M_{\text{bSSFP}}, A_{\text{SPGR}}, A_{\text{bSSFP}}, C\) and \(R(\alpha)\) are 3x3 (SPGR) or 9x9 (bSSFP) matrices containing the relative volume fraction, relaxation, off-resonance, exchange rate, and excitation flip angle (\(\alpha\)) terms.

Fitting of this model is performed via the stochastic region contraction approach outlined previously [4].

To demonstrate the method, in vivo sagittal adult data were acquired as: 22cm\(^2\)x17cm FOV; 128x128x98 matrix. SPGR: TE/TR=2.4ms/5.4ms; \(\alpha=(3, 4, 5, 6, 7, 9, 13\) and 18\(^\circ\); BW = 380 Hz/voxel. bSSFP: TE/TR=2.2ms/4.4ms; \(\alpha=(10, 13, 17, 20, 23, 30, 43,\) and 60\(^\circ\); BW=560 Hz/voxel. A reduced resolution IR-SPGR image was also acquired (TI=450ms), and the bSSFP data were acquired with 0 and 180\(^\circ\) RF phase-cycling patterns [4]. Following mcDESPOT processing [4], 2 and 3-pool models were fit to the data and the resultant MWF maps qualitatively compared.

RESULTS & CONCLUSIONS: Result 2-pool MWF and 3-pool MWF and bulk water fraction maps are shown in Fig. 2. Figure 3 shows a subtraction of the 3-pool model from the 2-pool model results. Marked increases in MWF (in some areas more 50%) are observed at the boundaries the ventricles and periphery of cortical grey matter in the 3-pool results. Within the ‘deeper’ grey and white matter, less than 3% difference is seen between the 2 and 3-pool models. In the AD patient results, the free water pool is also observed within the altered white matter. These results suggest the original 2-pool mcDESPOT implementation may be insufficient in specific brain regions or pathologically altered tissue, yielding a biased and under-estimated MWF value. Qualitatively, the 3-pool approach appears to correct for these issues, and may be a more suitable choice for investigations of disease.