Signal-to-Noise Ratio and Exchange effects on Myelin Water Fraction Estimations from Spin-Echo and Steady-State Techniques

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Target audience Those working with MR techniques for measuring myelin content.

Purpose Myelin water fraction (MWF) is conventionally measured by acquisition of the T_2 decay curve (1). Recently a steady state approach entitled multi-component driven equilibrium single pulse observation of T_1/T_2 (mcDESPOT) has also been employed for myelin water fraction mapping (2). Both data sets have been analyzed with a model containing an arbitrary number of T_2 components using a non negative least squares (NNLS) algorithm (3) (4). **The goal of this study was to investigate both signal-to-noise ratio (SNR) and exchange effects on the MWF estimation for both techniques**.

Methods Using the six coupled Bloch-McConnell equations (5), a two-pool model (myelin water and intra/extracellular water) was developed for the MR spin-echo and steady-state signal from white matter in brain. The effect of SNR on the accuracy of the NNLS analysis for both spin echo and steady state techniques was investigated. We created 1000 synthetic spin-echo (signal vs TE time) and 1000 synthetic bSSFP (signal vs flip angle) curves with MWF = 0.15 and with Rician noise added at SNR levels between 50 and 5000. By fitting each curve with a NNLS multi-component T_2 distribution model, MWF was calculated as the discrete integral for T_2 times from 15 to 40 ms normalized by the total area under the distribution. The effect of exchange on the spin-echo and bSSFP signal models was investigated using a two-pool model. We created 1000 synthetic spin-echo and 1000 synthetic bSSFP signal curves with myelin water residence times τ_M between 2000 ms and 20 ms. Each spin-echo or bSSFP signal was fitted using NNLS, to obtain T_2 distributions and MWF values.

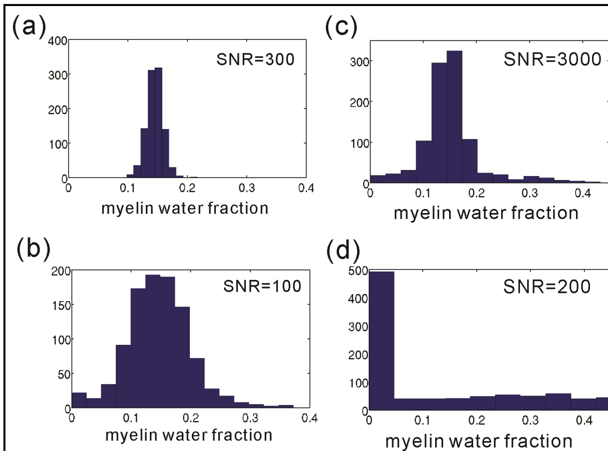

Figure 1. The histogram plot of MWF values by fitting spin echo signals ((a) and (b)) and bSSFP signals ((c) and (d)) with different SNR.

Results For any SNR value, the NNLS derived MWF histogram from the spin echo curves were much narrower than those derived from the b-SSFP curves (Figure 1). Typical experimental SNR values for the spin echo and b-SSFP curves are 300 and 200, respectively (6). For τ_M =100 ms, the MWF from spin-echo signal decreased from its no exchange value of 15% to 10%. Exchange had a much larger effect on MWF estimation from bSSFP signal which yielded a MWF of 0.92 at τ_M =100 ms (Figure 2).

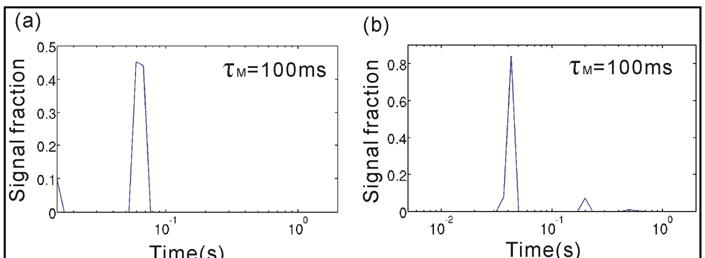

Figure 2. T_2 distribution plot for spin-echo and bSSFP two-pool signal at the same residence time τ_M =100 ms.

Discussion Our results indicate that for bSSFP signals analysed by NNLS, relatively slow exchange rates can result in artificially high measured MWF values. The conventional two-pool mcDESPOT technique includes exchange effects in the analysis; however it assumes only two pools and has parameter searching boundary constraints which result in larger fitting residuals than one obtains with NNLS.

Conclusion NNLS data analysis was applied to both spin-echo and mcDESPOT data to investigate the effect of SNR and exchange on measured MWF. This work demonstrates that, compared to spin-echo approaches to MWF measurement, steady state approaches are much more sensitive to SNR and exchange. At a practical SNR level, it is very difficult to get precise MWF prediction from the steady-state signal when the NNLS analysis method is used.

References

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