Quantification precision of human brain ^{1}H MRS at different field strengths: a simulation study

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Introduction

^{1}H MRS allows measurement of the concentration of a number of brain metabolites *in vivo*. It is generally accepted that the precision of quantification of metabolites improves at high field [1,2]. In principle, two factors may contribute to this increase in quantification precision: an increase in signal-to-noise ratio (SNR) and an increase in spectral resolution. The latter depends on chemical-shift dispersion which increases at higher field and on the minimum linewidth that can be achieved *in vivo*. We showed previously that the minimum total creatine linewidth in human brain increases linearly with B_0 (1.35 Hz/Tesla [3] from 1.5 Tesla to 9.4 Tesla). The goals of the present simulation work were 1) to assess the expected gain in quantification precision at very high field, and 2) to determine whether the gain in quantification precision can be attributed to increased SNR, increased spectral resolution, or both.

Methods

"Brain-like" ^{1}H NMR spectra consisting of 19 metabolites with appropriate concentrations were simulated to closely match *in vivo* brain spectra. Monte-Carlo simulation were performed for three different cases: 1) constant linewidth (5 Hz) and constant SNR (~22, measured in time domain) at all field strengths, 2) linear increase in linewidth as a function of B_0 (1.35 Hz/Tesla [3]) and constant SNR and 3) linear increase in linewidth and linear increase in SNR. In each case, simulations were performed at five different field strengths: 1.5, 3, 4, 7 and 9.4 Tesla. Each simulation was performed by generating 50 different ^{1}H spectra with different noise realizations and each spectrum was fitted with LCModel. This allowed determination of the average Cramer-Rao Lower Bounds (CRLBs) in each case.

Results and Discussion

The CRLBs of selected cerebral metabolites (taking Cr and PCr as examples of singlets and glutamate as an example of *J*-coupled metabolite) are shown in Figure 1. In case 1 (left column), we observed an increase in quantification precision (i.e. decrease in CRLBs) as a function of B_0 as expected due to the increased chemical-shift dispersion. In case 2 (middle column), the quantification precision of singlets degraded at higher B_0, consistent with the fact that the linewidth increased more quickly that than chemical-shift dispersion. The quantification precision of multiplets such as glutamate improved up to 3-4 Tesla then remained nearly constant at higher B_0. This suggests that, for a constant SNR in the time domain (same signal intensity detected by the coil), higher fields above 3-4 Tesla do not yield higher quantification precision. Finally in case 3 (right column) which corresponds to the actual *in vivo* situation, the quantification precision improved at higher B_0 and the increase in precision was more pronounced for *J*-coupled metabolites than for singlets.

In conclusion, our simulations show that quantification precision continues to improve in human brain at ultra high field and that most of the gain in quantification precision above 3-4 Tesla comes from increased SNR rather than increased chemical-shift dispersion.

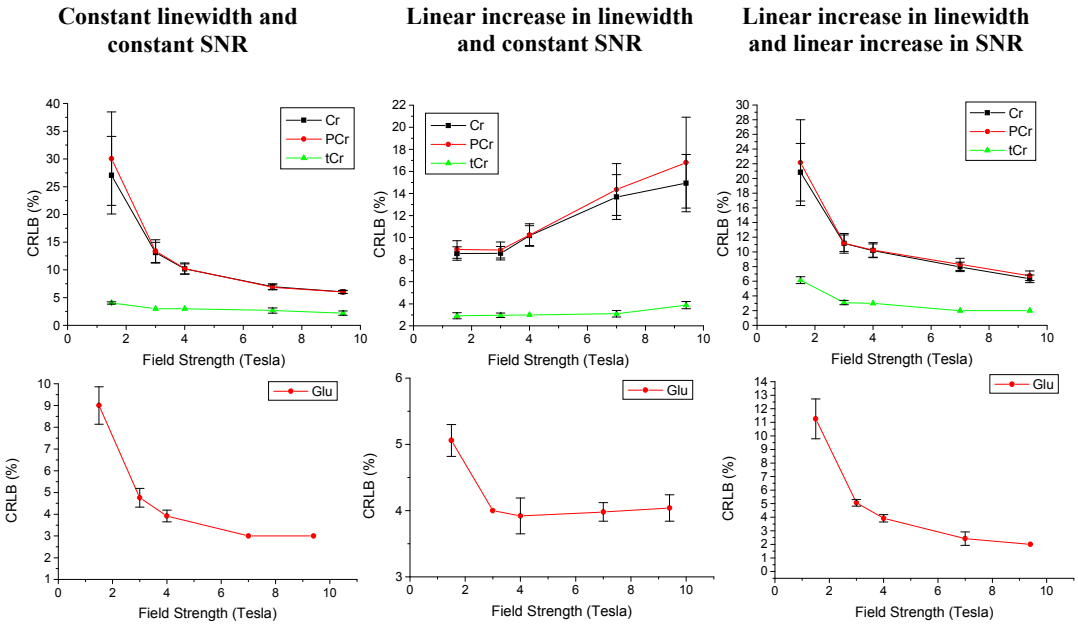

Figure 1: CRLBs (mean ± SD) determined from Monte-Carlo simulations (50 times, with different noise realizations) and LCModel analysis of simulated ^{1}H spectra at different field strengths.

References

[1] Bartha et al. MRM 2000; [2] Tkac et al. MRM 2009; [3] Deelchand et al. ISMRM 2009.

Acknowledgments

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