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

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.

References


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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.