Intravoxel incoherent motion (IVIM) imaging at different field strengths – what is feasible ?

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Introduction

Since the introduction of the intravoxel incoherent motion (IVIM) concept by Le Bihan [1], the cerebral applications of this technique have been sparse due to the limited SNR. However, MRI hardware development in general and increased main magnetic field strength specifically, could result in improved SNR and may justify a reassessment of IVIM imaging for non-invasive quantification of the cerebral blood volume (CBV) and cerebral blood flow (CBF) [2,3]. In this study, results from both simulations and experimental measurements are presented, and signal-versus-b curves at three different field strengths (1.5, 3 and 7 T) are shown as a first step towards determining the optimal field strength for IVIM imaging.

Subjects and Methods

Simulated signal-versus-b curves, S(b), were obtained for a synthetic voxel consisting of four compartments, i.e. cerebral gray matter (80%), cerebrospinal fluid (2%), arterial blood (3%, [4]) and venous blood (7%, [4]). Simulations were based on conventional signal equations for spin echo sequences including the IVIM-effect (Eq. 1).

$$S(b) = S(0)\left[(1-f)e^{-bD} + fe^{-b(D+D^*)}\right] \qquad \text{[Eq. 1]}$$

where D is the diffusion coefficient, D* is the pseudo-diffusion coefficient and f is the perfusion fraction . Values for T1, T2, D and pseudo-diffusion coefficient D* for the three magnetic field strengths were obtained from the literature.

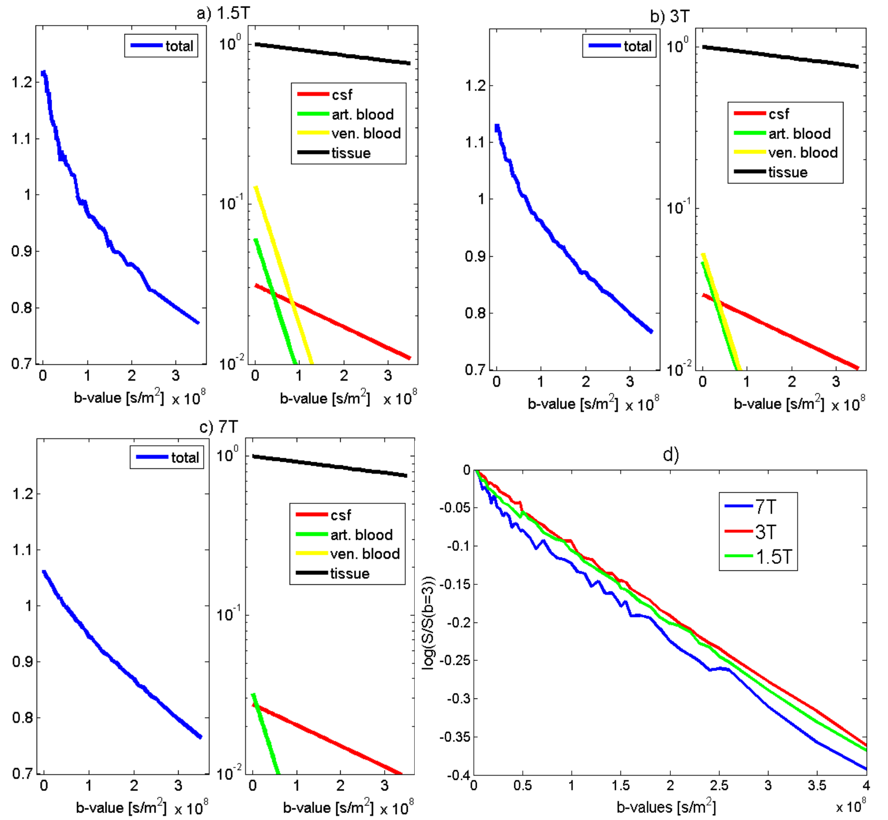

Figure 1. a-c) Simulation of S-vs-b curves at 1.5T, 3T and 7T, respectively. d) Experimental S-vs-b data from the thalamus region.

To confirm the results of the simulations, one volunteer was examined at three different field strengths within two days, using 1.5 T (Philips Intera), 3T (Philips Achieva) and 7T (Philips Achieva) whole-body MRI scanners. To facilitate comparison of the experiments, the imaging parameters were selected to be as equal as possible for all three field strengths. A spin-echo sequence with diffusion encoding in the phase-encoding direction was employed with b-values ranging between 0 and 900 s/mm^2. Imaging parameters were TR=3500 ms, FOV 220×220 mm^2, matrix size 80×80 and slice thickness 5 mm. The TE was 87, 70 and 62 ms at 1.5, 3 and 7T, respectively, due to different hardware requirements.
The experimental signal-versus-b data, obtained as the mean value of two ROIs placed in thalamus (left and right hemisphere), were normalized to the signal at b=3 mm^2/s to correct for differences in signal intensity between the different field strengths.

Results

The results from the simulations of signal-versus-b data for the three different field strengths are given in Figs 1a-c. The most prominent finding is that for higher field strengths the relative contribution from venous blood decreases. The experimental signal-versus-b curves for the thalamus ROIs, measured in the same volunteer at three different field strengths, are shown in Fig 1d.

Discussion

The most interesting finding from the simulation part is the vanishing contribution of venous blood to the IVIM signal at 7T, due to the short T2 of deoxygenated blood, suggesting that IVIM imaging at this field strength would primarily reflect arterial blood volume. This finding is in agreement with previous simulations of BOLD signal, showing a predominant sensitivity towards the extravascular signal at 7T [5].
The experimental signal data appear to be reasonably consistent with simulations at 1.5 T and 3T, showing a slightly decreased IVIM effect at 3T. The measurements at 7 T seem, however, to contradict the findings of the simulation study, by showing an increased IVIM effect. However, the SNR at the 7 T experiment is likely compromised, which limits the reliability of the result. The lower SNR might be attributed to more pronounced effects of physiological noise, eddy currents, or spurious echoes. The origin of this apparent decrease in SNR needs to be studied in more detail, before more firm conclusion may be drawn about IVIM at 7T.

References

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