Understanding the Principles and the Challenges of Intravoxel Voxel Incoherent Motion MRI

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Purpose

Separation of diffusion and perfusion signal has been proposed early as a possible application of the intravoxel incoherent motion (IVIM) MR imaging method [1]. While the measurement of diffusion showed a wide variety of clinical applications in the past 20 years, the measurement of perfusion using the IVIM method remained confined to a few sporadic publications, due to low signal-to-noise ratio, but showed nevertheless promising results in different organs such as brain, kidney, heart [2-4], most recently in the liver and muscle [5-6]. In the context of impressive improvements in the last few years in terms of both the hardware and software technology, such as the use of stronger magnetic fields, multichannel antennas and better pulse sequences, the IVIM method for measuring perfusion is back in focus. With rising concerns about nephrogenic systemic fibrosis induced by gadolinium-based contrast agents, the perfusion information obtained with the IVIM perfusion method, that does not require any contrast agent, could become invaluable in patients at risk. We will present the IVIM method applied to the measurement of perfusion with an emphasis on its use in the brain.

Outline of Content

The basic physical principle, its relation to the physiology of perfusion and the conceptual basis of the IVIM sequence will be presented. The IVIM sequence is based on a motion-sensitive MRI sequence, where random motion of the protons implies a phase incoherence of their spins at time of measurement and as a consequence, a drop in signal amplitude. Experimental evidence points to a double exponential decay of signal amplitude as a function of low diffusion weighing b (between b=0 and b=1000 s/mm2) in biological tissue. The IVIM perfusion theory hypothesize that the first exponential, measured for b above 200 s/mm2 is due to the molecular diffusion of water, while the second, steeper than the first and measured between b = 0 and b = 200, is due to the movement of protons with the blood flow in capillaries arranged in a randomly manner, called the perfusion or "pseudo-diffusion". An example in logarithmic scale is given in fig. 1 for a region of interest in the left thalamus of a human brain. Separation of diffusion and perfusion signal is done through proper fitting of a double exponential parametrical function to the experimental data, and will be discussed. The theoretical assumptions under which the method can be applied will be discussed, followed by a challenge of the theory to the already published experimental data, as well as our own data obtained in the brain. The presentation will be closed by a discussion of the advantages, limitations, remaining challenges to bring this technique to clinical use and potential interpretation pitfalls of the technique.

Summary

The IVIM perfusion method has major advantages in comparison to the sequences used nowadays to measure perfusion, especially the no-need of gadolinium-based contrast agents and its intrinsic quantitative nature. In the context of recent improvements in MRI technology, the method could become rapidly a useful alternative in clinical daily life.

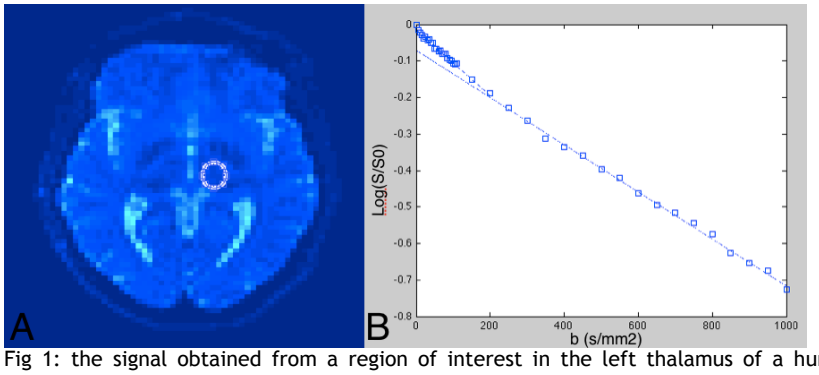

Fig 1: the signal obtained from a region of interest in the left thalamus of a human brain (A) decays as a double exponential as function of diffusion weighting b (B). The proper mathematical fitting of these data to a parametrical double exponential function allows the separation of the perfusion signal form the diffusion signal.

Reference

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