

Human Brain Intravoxel Incoherent Motion (IVIM) : Optimized set-up for clinical investigation

Alberto Ciarmatori^{1,2}, Elisa Cenacchi¹, Tiziana Costi¹, and Luca Nocetti¹

¹Medical Physics Department, University Hospital "Policlinico", Modena, Italy, ²Medical Physics School, University "Alma Mater Studiorum", Bologna, Italy

Target Audience: Not all Medical Doctor, Neuroradiologist and Medical Scientist know how to perform an IVIM MRI scan of the human brain and so the associated clinical information (useful in case of cancer staging, response to antiangiogenetic therapy, stroke etc...) are often not taken into consideration.

Purpose: Human Brain DWI is a technique implemented in many clinical MRI scan protocol and Apparent Diffusion Coefficient (ADC) maps are widely used for qualitative and quantitative pathologies assessment. These maps are calculated considering a mono-exponential signal decay vs b-values. However a different decay of DWI Signal, due to the presence of water molecules in different compartment (eg capillary), can be observed if low b-values ($b < 150 \text{ s/mm}^2$) are taken into account. Neglecting this component may lead to erroneous consideration. For these reasons, Le-Bihan proposed a bi-exponential model to separate capillary perfusion and Brownian diffusion [1]: MRI Scans with multiple b-values are acquired in order to identify the different compartments. This study focused on the choice of the best fit function for the DWI signal decay, on fit parameters characterization in white and gray matter of the human brain and on the temporal optimization of the sequence for the implementation into clinical practice.

Methods and materials: Brain scans were performed using a 3T whole body MR-system (Philips Achieva, Best, Netherlands), Dual Nova gradients (80mT/m, 200 T/m/s) and Sense Head Coil on six healthy volunteers. DWIs with multiple b-values (0-5-10-20-30-40-50-75-100-150-200-300-500-1000 s/mm^2) were obtained (3 orthogonal directions - 2 NSA - 18'36" sequence time). The images were co-registered to the b0 and segmented into white and grey matter[2]. Regions of interest (≈ 30 pixel) were placed on the segmented images to evaluate the behaviour of the tissues. Trace images were fitted with 4 different functions a) standard mono-exponential, b) free bi-exponential, c) bi-exponential with "True" diffusion coefficient- D fixed and d) bi-exponential with D and perfusion fraction- f fixed). For functions c) and d), D and f were obtained starting from a mono-exponential fit of high b-values ($> 250 \text{ s/mm}^2$). For every fitting function, fitting parameters (eg D , f , Perfusion related coefficient- D^*) and correlation coefficient (R^2) maps were calculated with the 95% confidence interval (CI).

confidence interval (CI). To optimize sequence time, images of each volunteer were elaborated taking into account ten different b-values set-up, varying both low ($< 250 \text{ s/mm}^2$) and high b-values (see table). Mean, standard deviation and confidence interval of the estimated parameter (D , D^* , f) were compared with the "full b-values" set-up to establish the most appropriate protocol to implement in clinical practice.

Results and Discussion: All the fitting functions but the monoexponential one show good agreement with experimental data. The best

fitting function, decided on both R^2 and 95% CI, is the biexponential-fit with D and f fixed (function d). Significative differences ($p < 0.005$) were observed among the calculated true diffusion coefficient and standard ADC as well as between grey matter and white matter diffusion parameters. In particular D^* of grey matter resulted significant greater than in white matter. This result agreed with MTT obtained from DCE data[3]. A good compromise between sequence time and robustness of the fit was found: the set-up (J) with b-values 0 – 40 – 75 – 100 – 300 – 1000 s/mm^2 (6'30" sequence time) allowed to contain difference from the complete set-up to acceptable values (<5% mean values – standard deviation – 95% confidence interval).

Conclusion: Different brain diffusion parameters have been characterized with good and robust confidence both in grey and in white matter, moreover a temporal optimized protocol has been defined and it is now ready for clinical implementation.

References:

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