Investigation of the Presence and Repeatability of Intravoxel Incoherent Motion (IVIM) in Breast Parenchyma of Healthy Volunteers using an Optimised b-value Scheme

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TARGET AUDIENCE: MR breast researchers – scientists and clinicians

PURPOSE: Tissue diffusion and perfusion are important biological parameters that prove to be advantageous for the detection of disease or treatment response. Intravoxel incoherent motion imaging (IVIM) is a technique that enables the measurement of cellularity and vascularity using diffusion-weighted (DW) imaging. [1] The IVIM technique has been applied to various cancer types including breast cancer [2, 3, 4], however it has been argued that there is no or very little perfusion effect in breast parenchyma.[2, 5] Adding to studies to resolve whether there is an IVIM effect in breast parenchyma may help avoid systematic error. Furthermore, many b-value schemes used in IVIM are heuristic. The spacing and number of b-values used strongly affects the IVIM parameters and their values in cancerous and normal tissue.[3] Recently the issue of 'optimal' b-values for IVIM has been considered.[6] Using optimised protocols, this study aims to investigate the presence and repeatability of IVIM in breast parenchyma of healthy volunteers.

METHODS: The Cramer-Rao Lower Bound (CRLB) of the standard deviation of the 4 IVIM equation parameters (perfusion fraction, f, diffusion coefficient, D, pseudo diffusion coefficient, D* and DW-signal, S) were computed in MATLAB (MathWorks, MA, USA) using sets of exponential and power-law spaced b-values from 0 s/mm^2 to 1000 s/mm^2 with spacing coefficients sampled from 0 to 10 in increments of 0.01 for 10 and 20 b-values. Two optimised b-value schemes were chosen based on their figure of merit (a calculation to balance the relative errors of the parameters of interest), NEX and scan time with a view to being applied clinically. The two b-value schemes used were: b-values$_{10}$= 0, 10, 23, 46, 82, 140, 233, 382, 619, 1000 s/mm^2 and b-values$_{20}$ = 0, 10, 10, 14, 21, 30, 41, 55, 73, 94, 122, 156, 198, 251, 318, 401, 505, 635, 797, 1000 s/mm^2. Note two 10 s/mm^2 as system would not allow 4 s/mm^2 and 8 s/mm^2. DW-images of 11 healthy volunteers with a median age of 24 years (Range 21 to 54 years) were acquired on a 3.0T MR750 scanner (GE Healthcare, Milwaukee, WI). DWI was performed with an 8-channel breast coil using single-shot echo planar imaging (34x34cm field of view, 128x128 matrix, 4m20s scan duration) with water only excitation. Four series per volunteer were acquired: two repeats of b-values$_{10}$ (4 NEX) and two repeats of b-values$_{20}$ (2 NEX). Region of interests (ROIs) were drawn in the breast parenchyma, with a mean area of 82mm^2. Firstly, this signal data was fitted using a monoexponential model to calculate D_m. Then the data was fitted to the biexponential IVIM equation using the Levenberg-Marquardt algorithm implemented in MATLAB. The curve was fitted with a cut-off value of b = 200 s/mm^2 for the single parameter D to neglect D* for b-values greater than 200 s/mm^2. The curve was then fitted for f and D* over all b-values whilst keeping D constant. This increased robustness. The root mean square error (RMSE) for each fit was reported. The repeatability was then calculated for the two protocols for each parameter along with the standard deviation.

RESULTS: Table 1 shows the results for the mean of all the RMSEs of the monoexponential and IVIM fits, and the repeatability of f, D and D*. The mean values for f, D and D* in breast parenchyma using b-values$_{10}$ were 0.056, 0.0018 s/mm^2, and 0.0085 s/mm^2 and for b-values$_{20}$ were 0.063, 0.0018 s/mm^2, and 0.010 s/mm^2 respectively.

DISCUSSION: The mean RMSE indicates that the fits for both b-value schemes are both reasonably good and similar in the IVIM model, and the mean RMSEs for the monoexponential are higher in comparison. The repeatability for all parameters is better using b-values$_{10}$. The repeatability of D is good at 9% and 20% for b-values$_{10}$ and b-values$_{20}$ respectively. Both protocols had the same scan duration, b-values$_{10}$ had more NEX and has a better repeatability therefore it apparently would be the best choice for clinical studies out of the two protocols. The values for f, D and D* agree well with previous reported values.[2, 3, 4] It is expected that D would be around one order of magnitude lower than D* in breast parenchyma since the degree of the restriction of the cellularity is not high.[2] The results show that there are perfusion effects in breast parenchyma. These effects are not high in comparison to other organs but are still significant.

b-value protocol	*Mean of all mono-exponential RMSEs*	*Mean of all bi-exponential RMSEs*	*Repeatability of f*	*Repeatability of D in s/mm^2*	*Repeatability of D* in s/mm^2*
b-values$_{10}$	16	13	±0.084	±0.00016	±0.021
b-values$_{20}$	14	12	±0.12	±0.00035	±0.039

Table 1: *Repeatability results for parameters f, D and D* for b-values$_{10}$ and b-values$_{20}$.*

CONCLUSION: The repeatability of IVIM in breast parenchyma of healthy volunteers has been assessed, and shows that some parameters may have significant variation. The mean RMSEs indicated that the biexponential fit was better for this data. Breast parenchyma was found to have perfusion effects.

REFERENCES

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