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Does Intravoxel Incoherent Motion (IVIM) introduce a new biomarker in MRI?

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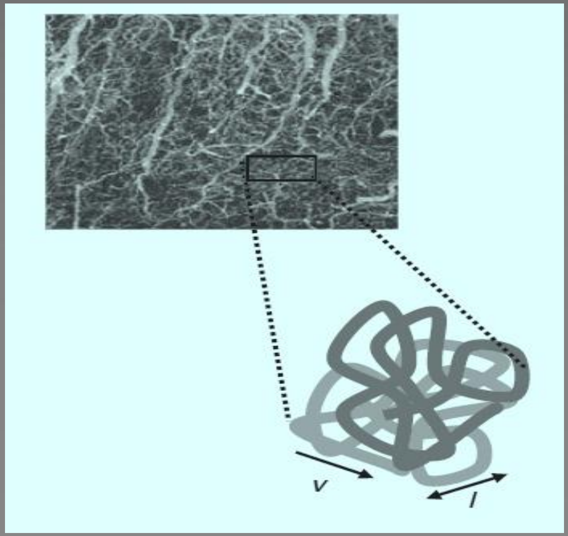
Introduction

IVIM imaging is a method that provides quantitative assessment all of the microscopic translational motions that could contribute to the MR signal. The fundamental idea was that the molecular motion of water is randomly oriented in the capillary network at ultralow b values of diffusion weighted imaging (DWI), mimicking a random walk.

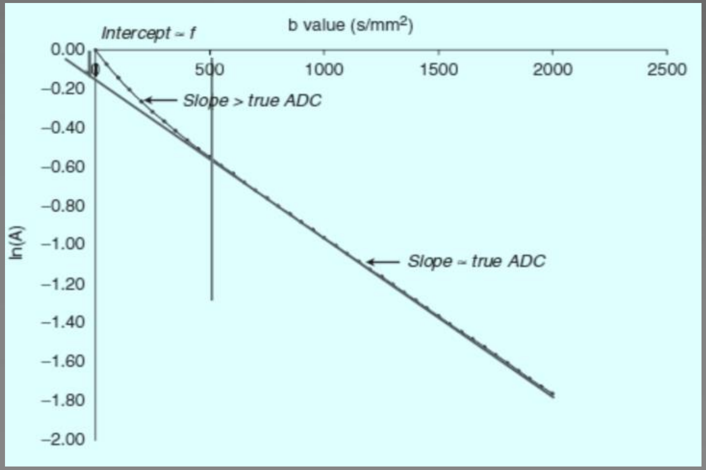


Introduction

IVIM model assumes that the signal attenuation S/S_o is a combination of two exponentials compartments, one for microvascular and one for nonvascular process with pseudo-ADC(D_{fast}) and true-ADC(D_{slow}) the diffusion coefficients, respectively, described by the equation:

$$\frac{S}{S_o} = f \cdot e^{-b \cdot D_{fast}} + (1 - f) \cdot e^{-b \cdot D_{slow}}$$

where *f* is the perfusion fraction.



Purpose

- To quantify the IVIM model diffusion parameters *f*, D_{fast} and D_{slow} by using three different curve fitting models and find the more robust technique.

- To investigate probable differentiations of the IVIM model diffusion parameters in patients with brain lesions compared to normal appearing contralateral regions of the brain.

Methods

3T Philips MRI

7 patients

Single-shot spin echo planar imaging(EPI) sequence

10 b values(0,10,15,50,80,100,200,400,700,1000 s/mm²).

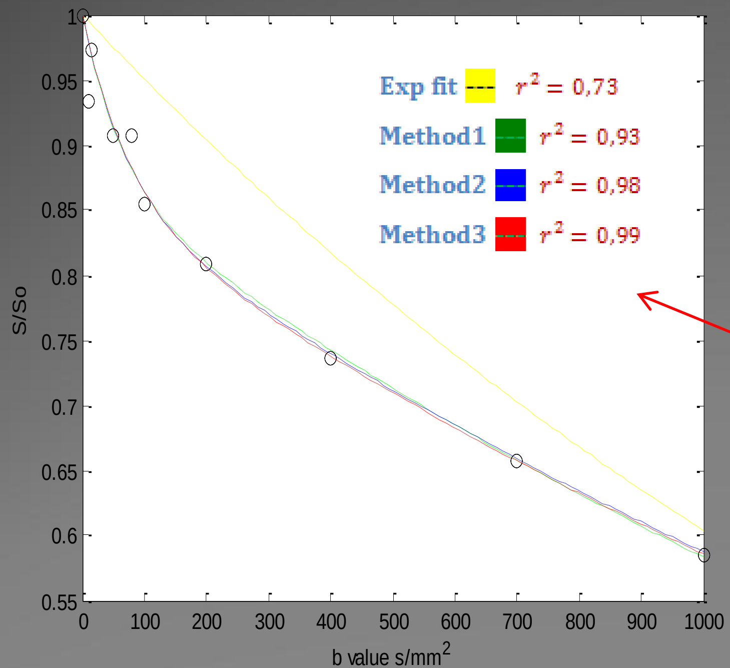
The three fitting processes were based on Levenberg-Marquardt algorithm applied in an in-house platform in Matlab :

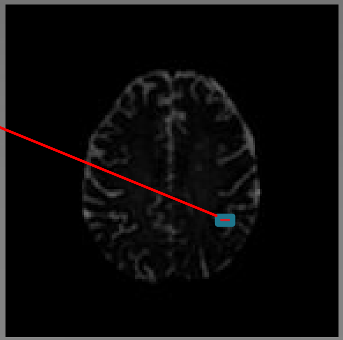
- Method 1: Three parameters fit (f, D_{fast}, D_{slow})
- Method 2: Linearly fit D_{slow}(high b) and then fit f, D_{fast}
- Method 3: Linearly fit f,D_{slow} (high b) and then fit D_{fast}

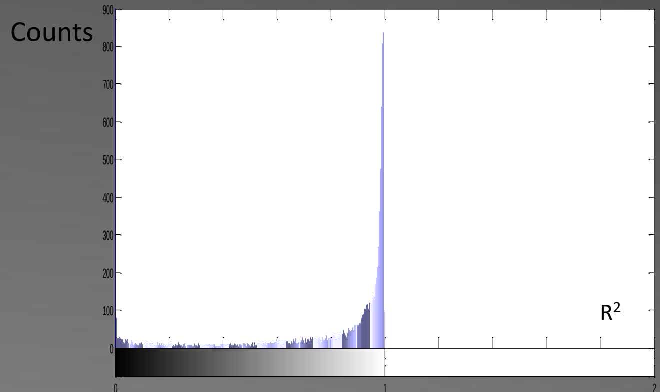
R^2 criteria was used for comparison of the 3 methods.

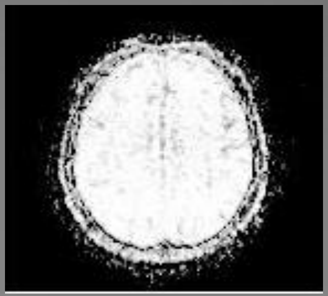
Results

Method 3 describes a better fitting process for the majority of pixels. Histogram for the counts of R^2 near unit was 49,72% for method 3, 46,99% for method 2 and 43,44% for method 1.









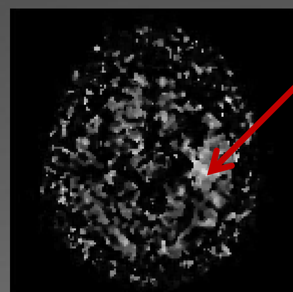
R^2 map

Results

Case 1: Increased values of *f (hyperperfusion).*

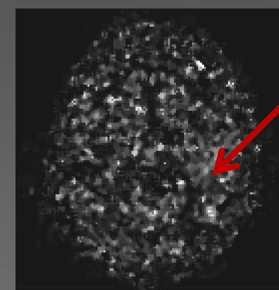
Case 1: Inflammation

b= 0 s/mm²



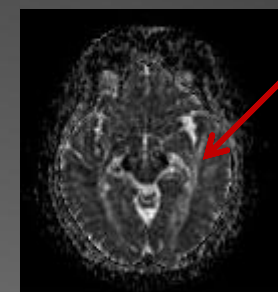
F map

0.12 ±0.07 versus 0.07± 0.03



Dfast ($10^{-3}mm^2/s$)

10.7 ±5.2 versus 10.1± 8.2

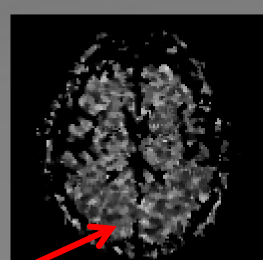


Dslow ($10^{-3}mm^2/s$)

1.5±3.2 versus 1.7± 5.0

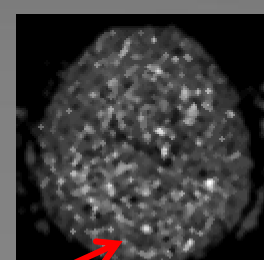
Case 2: Press

b= 0 s/mm²



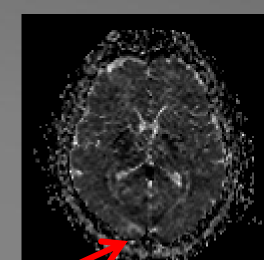
F map

0.09±0.06 versus 0.09± 0.05



Dfast ($10^{-3}mm^2/s$)

6.2±7.0 versus 6.4±7.1



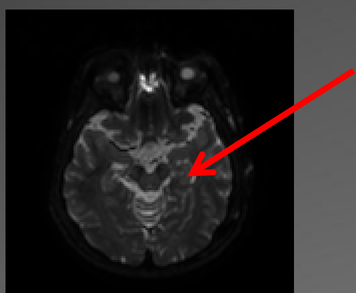
Dslow ($10^{-3}mm^2/s$)

0.9±0.3 versus 0.9± 0.4

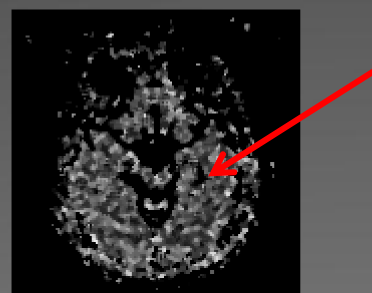
Results

Case 3: decreased values of *f (hypoperfusion).*

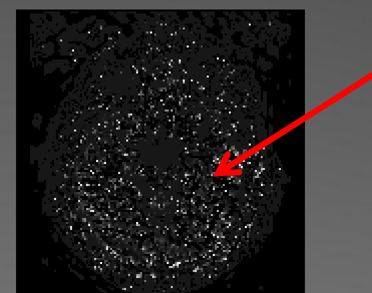
Case 3: Gliosis



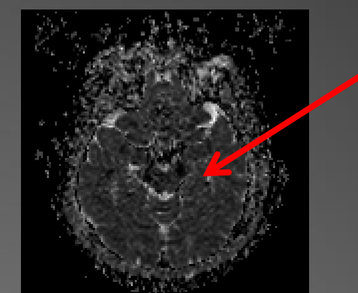
b= 0 s/mm^2



F map
0.08 ±0.05 versus 0.10± 0.06

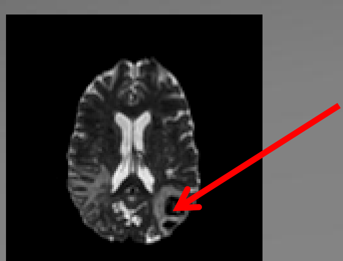


Dfast ($10^{-3} mm^2/s$)
5.7 ±6.3 versus 5.8± 7.1

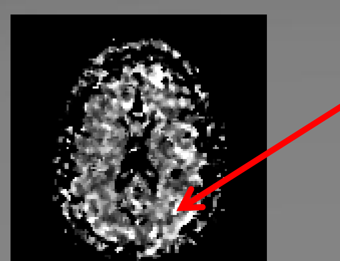


Dslow ($10^{-3} mm^2/s$)
1.0±0.8 versus 0.9± 0.5

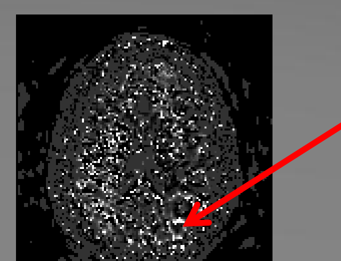
Case 4: Ischemia



b= 0 s/mm^2



F map
0.12 ±0.06 versus 0.10± 0.06



Dfast ($10^{-3} mm^2/s$)
6.1 ±5.6 versus 5.8± 6.2

Dslow ($10^{-3} mm^2/s$)
0.9±0.7 versus 0.8± 0.7

Results

Other cases

Position of ROI	IVIM parameters	ROI of interest	Contralateral ROI
Case 5 Tumefactive multiple sclerosis	***f*** **Dfast**($10^{-3}mm^2/s$) **Dslow**($10^{-3}mm^2/s$)	0.10±0.08 5.6±5.2 0.9±0.7	0.09±0.07 4.5±6.2 0.8±0.6
Case 6 Propability of lemphoma or encephalitis	***f*** **Dfast**($10^{-3}mm^2/s$) **Dslow**($10^{-3}mm^2/s$)	0.08±0.06 4.8±5.4 0.8±0.6	0.07±0.08 6.5±6.3 0.9±0.8
Case 7 Cortical dysplasia or low grade tumor	***f*** **Dfast**($10^{-3}mm^2/s$) **Dslow**($10^{-3}mm^2/s$)	0.09±0.06 5.4±4.8 0.4±0.2	0.10±0.07 5.5±5.2 0.4±0.3

Parameters of D_{fast} and D_{slow} do not seem to expose any significant differentiations.

Conclusion

Perfusion fraction *f* may consist a new sensitive biomarker for providing additional information to conventional diffusion parameters.