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Optimal ROI Size for IVIM Imaging parameter determination

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Authors: M. Montelius, M. Ljungberg, E. Forssell-Aronsson; Gothenburg/SE

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1. Purpose

The use of multiple b-values in diffusion weighted (DW) imaging allows calculation of the tissue molecular diffusion parameter D, the perfusion-related diffusion parameter D* and the perfusion fraction f, by applying the intravoxel incoherent motion (IVIM) model (Le Bihan 1988). Region of interest (ROI) based signal analysis is a widely used approach, where the normalized average ROI signal is plotted vs. b-value, and the acquired signal decay curve is fitted to a bi-exponential model in order to extract D, D* and f. However, the use of this approach requires consideration regarding the ROI area used for signal averaging, since a too small area would lead to uncertainties in the parameter determination, e.g. due to noise and patient motion. Likewise, a too large area increases the likelihood of including unwanted large vessels in the ROI, which confounds the interpretation of the perfusion fraction parameter. Better knowledge on how to choose the ROI size could lead to better and more reproducible estimations of D, D* and f; important parameters in e.g. tumor therapy response assessment. Our objective is to investigate the variability of these parameters due to the use of different ROI areas in liver IVIM experiments, and thereby empirically determine an optimal area for signal averaging.

2. Material and Methods

Liver IVIM MRI was performed on four healthy adult volunteers after obtaining informed consent. MR system and coil configuration: 3T Philips Achieva with 16 channel torso XL-phased array surface coil (Philips Medical Systems, the Nederlands). DW SE-EPI parameters: respiratory navigator (trig and track 8 mm window); b-values: 0,5,10,20,30,40,50,75,100,200,400,800; fat suppression: SPIR; TR/TE/NSA=2000/53/2; pixel size: 1.46*1.46 mm^2; slice thickness: 5 mm; SENSE factor = 2; total scan time including triggering ~12 min. ROI averaged signal-intensity decay curves were acquired from four positions in the liver parenchyma (Fig. 1). Eight ROI sizes, each with a one pixel increase in radius compared to the preceding ROI, were analyzed for each position [ROI no 1-8: 2, 19, 53, 104, 173, 258, 360 and 480 mm^2]. Each of the 128 resulting signal decay curves were fitted to the bi-exponential IVIM model function (Le Bihan 1988) using Matlab (The Mathworks, USA), and D, D* and f were extracted together with a goodness of fit parameter (SSE = sum of squares due to error). The variation of the parameters with increasing ROI radius was analyzed by calculating the derivative of D, D* and f with regard to ROI radius, thus producing the variables dD/dr, dD*/dr and df/dr for each of the four positions in each liver. The magnitudes of the derivatives were averaged for each size increment and their standard deviations were calculated. This was plotted vs. ROI radius.

3. Results

Fig. 1 shows an example of a b=0 IVIM image of the liver with the ROI positions marked with red dots in the liver parenchyma. The inserted figure shows the eight ROI areas used for signal averaging (red disks).

Fig. 1

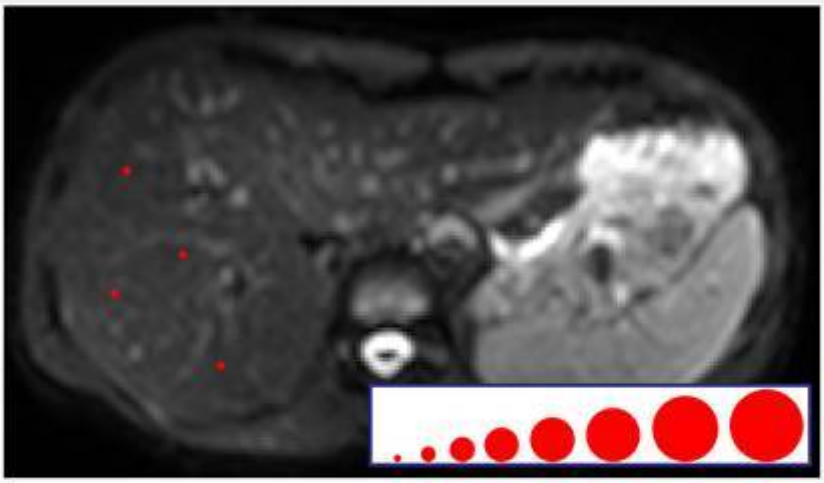
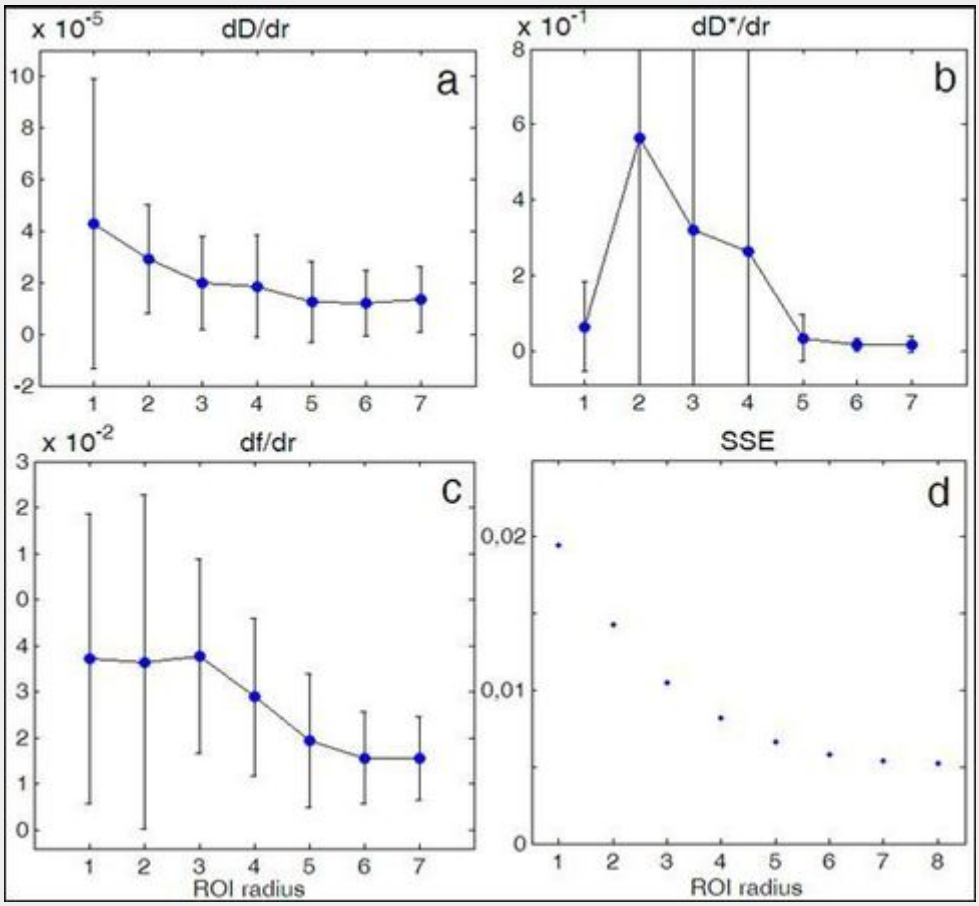


Figure 1. IVIM (b=0) image of liver with ROI positions and sizes shown. 2, 19, 53, 104, 173, 258, 360 and 480 mm^2.

Fig. 2a-c show the average magnitude of dD/dr, dD*/dr and df/dr with increasing ROI radius for the different ROI radii investigated. Parameters D and f show a lower uncertainty and a plateau in their variation with increasing radius. D* appears relatively stable first, but behaves like D and f for radii larger than 2 pixels (note the scale of the y-axes). The SSE vs. radius plot (Fig. 2d) shows that the parameters are better fitted to the model with increasing ROI radius

Fig. 2. Parameter variation with increasing ROI radius



The parameter variation with increasing ROI radius is plotted vs. ROI radius in a), b), and c) for the pure molecular diffusion parameter (D), the perfusion related diffusion parameter (D*) and f, respectively (error bar = std). The corresponding average goodness of fit parameter SSE is shown in d). Note the scales of the y-axes when comparing a), b) and c).

4. Conclusion

The initial parameter variability seen in Fig. 2 indicates, as expected, that such small ROI areas should be avoided to ascertain reproducibility in the parameter determination. This is further supported by the goodness of fit parameter SSE, which asymptotically approaches a minimum (best fit to model) at about ROI size 5-6. The curves in Fig. 2a, b and c indicate a plateau at about ROI number 5-6, corresponding to approximately 170-260 mm^2, or disk 5-6 from the left in Fig. 1. Fig. 2c shows that the variation of f does not reach zero. A possible explanation for this is that more vessels are included in the increasing area and therefore increases the perfusion fraction. Interestingly, Fig. 2a shows the same behavior, although D is expected to stabilize (reach zero). This implies that D in tissue included in larger ROIs varies. Note however, the scale of the vertical axis, which implies a very small variation in D for larger ROIs.

The optimal area should be around the beginning of the plateau, which is common for a), b) and c), and we therefore recommend using a ROI of approximately 5-6 pixels in radius where possible. This corresponds to about 170-260 mm^2, or ROI number 5-6 from the left in Fig. 1.

5. Mediafiles

Fig. 1

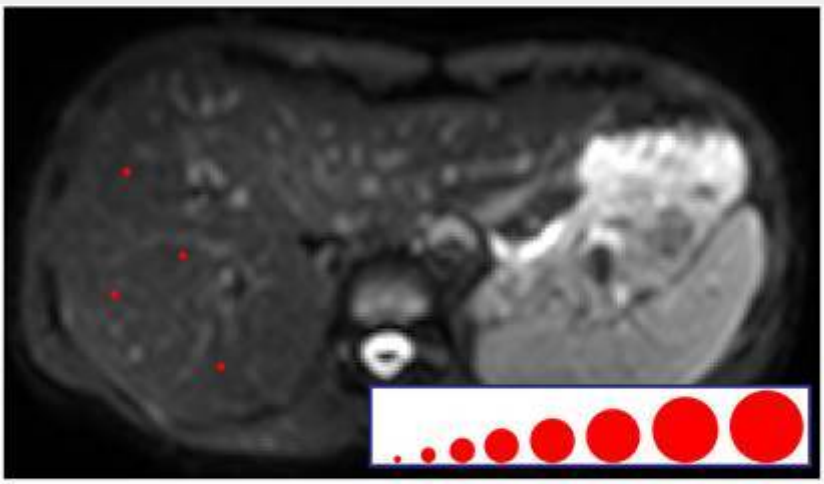


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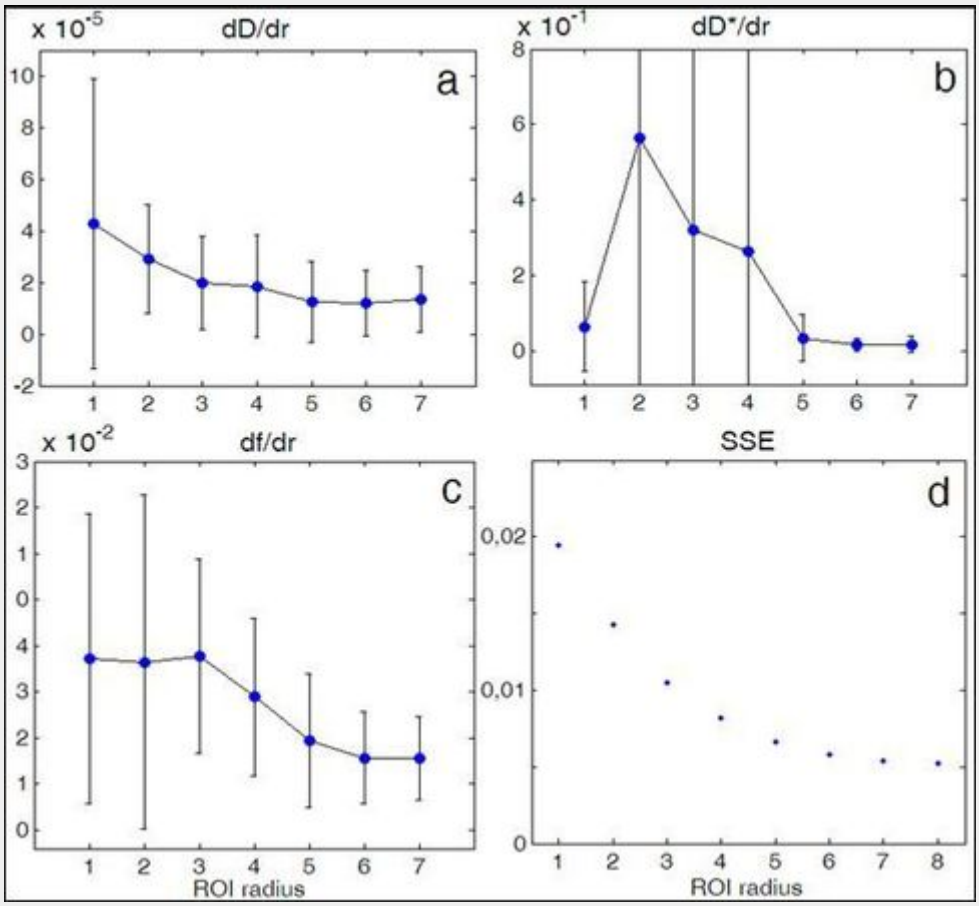
Fig. 2. Parameter variation with increasing ROI radius



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