A comparison of the full and segmented IVIM models in the liver
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Target Audience
Body imaging researchers and clinicians

Purpose
Intravoxel Incoherent Motion (IVIM) imaging has been increasingly used in body MRI to assess liver cirrhosis1,2 and to evaluate renal lesions3, however, the best way to collect and analyze this data remains unknown. The IVIM technique involves the collection of multiple b-values to extract perfusion-related diffusion parameters. Data can be collected in a breath hold (BH), during free breathing (FB), or respiratory triggered (RT) and with different diffusion directions and diffusion weightings (b-values). The 3dir method acquires three orthogonal directions and averages them while the 3in1 method applies three gradient directions simultaneously. Furthermore, there are multiple ways to calculate IVIM parameters. The segmented technique involves using only high b-values to calculate a perfusion insensitive diffusion parameter and fractional perfusion. The full technique involves fitting the entire equation. This study examines the parameter values and repeatability of the two fitting techniques for various combinations of triggering technique and diffusion direction in the liver of healthy control subjects.

Methods

Imaging Eight subjects with no known history of abdominal disease participated in this study. Each subject underwent two consecutive imaging sessions on a GE 1.5T scanner. Each session consisted of four DWI scans with various combinations of triggering technique and diffusion directions. FOV ranged from 36-50cm with a slice thickness of 8mm and skip of 2mm. These scans are summarized in Table 1. Data Analysis IVIM modeling was performed using both the full and segmented models. All curve-fitting analyses were accomplished using Matlab and a Levenberg-Marquardt algorithm. For the full model, the multiple b-value data was fit to Equation 1, where \( f_p \) is the fractional perfusion, \( D_p \) represents the pure molecular diffusion, and \( D_t \) is the pseudodiffusion, or perfusion related diffusion. The segmented approach takes advantage of the fact that since \( D_t \gg D_p \), it’s effect can be neglected when \( b \geq 200 \text{s/mm}^2 \). Thus, \( D_p \) can be estimated by linearly fitting the natural log of Equation 2, and \( f_p \) by evaluating Equation 3. \( D_p \) can then be calculated by fitting Equation 1 with \( f_p \) and \( D_t \) already known. To compare full and segmented IVIM parameters, 20mm radius circular ROIs were drawn in segments 5/6 in the lower right lobe of the liver. Median values of each parameter were extracted on a voxelwise basis within the ROI. The DWI signal was also averaged within the ROI and the averaged signal was then fitted with each model. Repeatability was assessed within the subject coefficient of variation (CV). Examples of IVIM maps are shown in Figure 1. The results were mixed when comparing the voxelwise and ROI-based analysis methods. The ROI method tended to have lower CV values than the voxelwise method. This is driven by the pseudodiffusion term, which had a markedly lower CV for the ROI-based method compared to the voxelwise method. Finally, in terms of scan type, the RT scans tended to have lower CV values compared to the FB scans. The average values of all parameters were not significantly different between the full and segmented model except for the fractional perfusion calculated with the voxelwise method, where the full model gave significantly higher values compared to the segmented model (p=0.003).

Discussion
The segmented method for calculating IVIM parameters tends to be more robust than the full method leading to parameter maps that are qualitatively better. With the segmented method, the calculation of \( f_p \) and \( D_p \) amounts to a linear fitting of the signal from the high b-value data and a subsequent non-linear fit to extract \( D_t \). With the full model, the calculation of all parameters results from a non-linear fit of three variables and leads to more fitting errors. Another advantage of the segmented method is it is computationally faster. The linear fit of Equation 2 can be accomplished almost instantaneously.

Conclusion
The segmented and full IVIM models had comparable repeatability metrics. Due to lower CV values compared to FB scans, RT scans are recommended for IVIM liver studies. The segmented model can be used when generating parametric maps and performing a voxelwise analysis to speed up computation time without compromising repeatability.

References