Effect of nutritional state on IVIM parameters measured with multiple b value diffusion MRI

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Introduction: Existing studies of diffusion MR in the liver have demonstrated moderate variability in ADC out of proportion to other abdominal organs [1-3]. This has been attributed to inherent measurement errors, transient changes in portal venous flow or due to relatively short T2 in the liver which increases the noise in the ADC measurement. However, these functional studies of the liver do not appear to take into account the massive increase in splanchnic/portal blood flow that occurs after eating [4]. In an attempt to assess the effect of these postprandial blood flow changes on MR diffusion measurements, 4 male volunteers were scanned in a fasting state on two separate days as well as in a post-prandial state. Our hypothesis is that increased portal perfusion after eating causes alteration of IVIM (intravoxel incoherent motion) parameters as measured by diffusion weighted EPI with 10 increments of b values (ranging from 0 to 800).

Method and Materials: Four healthy male volunteers aged 25-36, mean weight 76 kg, underwent MR diffusion scans after an 8 hour fast and then again approximately 1 hour after drinking 500 cc of a balanced nutritional supplement drink (400kcal, 36g protein, 40g carbohydrates, 10g fat). These same volunteers were imaged on the same 1.5T system after an 8 hour fast one week later. All scanning was performed on the same 1.5T Siemens MAGNETOM Avanto MRI scanner (Erlangen, Germany) with a respiratory-gated, single-shot, diffusion-weighted EPI sequence with monopolar diffusion encoding and adiabatic fat suppression (SPAIR). Pixel spacing was 2.4 X 2.4mm, slice thickness 6mm, slice gap 1.2mm, matrix 86X144 and TE was 50ms. TR was dependant on volunteer breathing cycle. A wide range of b values were scanned (0, 10, 20, 30, 50, 75, 100, 200, 400, 800).
A custom-build analysis package was built in-house for analyzing the results. A four parameter biexponential IVIM fit [5] was applied according to the following equation

$$S(i) = S_0\left((1-pf)*\exp(-b_i * D) + pf * \exp(-bi * D^*)\right)$$

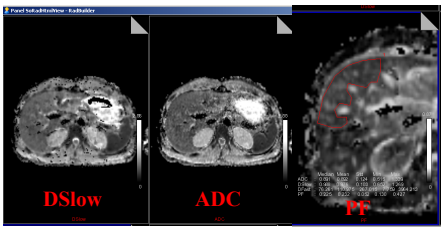

Figure 1: Screenshot of computed images. The ROI was drawn to avoid large blood vessels. Dslow = the slow components of the diffusion fraction, Dfast = the fast components of the diffusion fraction (affected by gross bloodflow), ADC = apparent diffusion coefficient, pf = perfusion fraction.

using a Levenberg-Marquardt optimizer with S(i) being the measured signal intensities and *bi* the applied b values, S_0 the fitted b0 amplitude, D the diffusion coefficient, D* the pseudo-diffusion coefficient and pf the perfusion fraction. Weak Gaussian filtering on source images was applied for robust fitting. In addition ADC was calculated by linear regression to the logarithm of the signal a) using all b values yielding ADC_{Total} and b) using only high b values (b>=100) yielding ADC_{High}. ROI's were drawn in the right lobe of the liver to exclude large blood vessels and areas of severe image artifacts (Fig 1).

Results: Although there were no statistically significant differences between diffusion coefficients and perfusion fractions in the pre- and post-prandial measurements, Figure 2 demonstrates that there was a strong trend towards an increase in the perfusion fraction after the liquid meal, and towards a decrease in the other calculated values. In comparison, there is essentially no trend seen in the two fasting studies performed a week apart. This suggests that given similar examination conditions, the feeding state of the subjects may have more of an affect on diffusion imaging than the inherent variability in the imaging system.

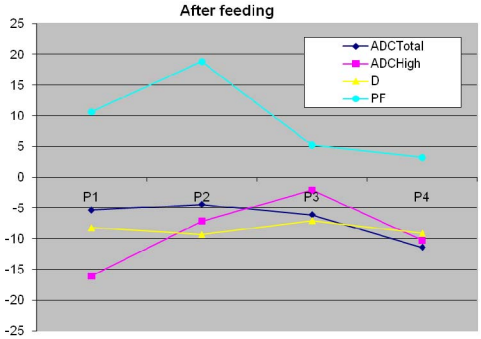

Figure 2: Relative changes in the diffusion components after a liquid meal. Notice perfusion fraction is consistently elevated after the meal while the other components are decreased. ADCTotal = the apparent diffusion coefficient including all b values measures, ADCHigh = the apparent diffusion coefficient excluding the low B values (less perfusion sensitive), D = the true diffusion coefficient, PF = the perfusion fraction.

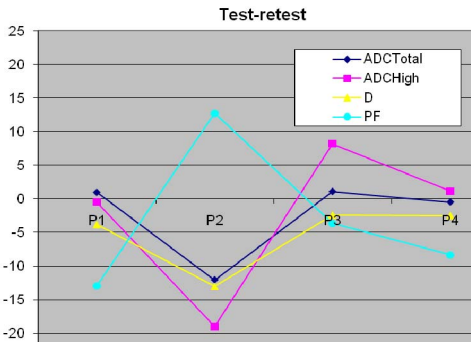

Figure 3: Relative changes in the diffusion components from fasting studies a week apart. Notice that there is no consistent change on these two days. ADCTotal = the apparent diffusion coefficient including all b values measures, ADCHigh = the apparent diffusion coefficient excluding the low B values (less perfusion sensitive), D = the true diffusion coefficient, PF = the perfusion fraction.

Conclusion: This pilot study demonstrates that digestion likely does have an impact on diffusion imaging within the liver. An increase in liver perfusion was noticed after food intake, which affected the diffusion coefficients. Although this data is encouraging, it is still highly preliminary, and no statistical significance was found. Further experiments with a larger number of patients will hopefully reinforce this trend and yield significant statistics. In summary, future studies involving liver diffusion probably should take into account patient feeding state (pre- vs. post-prandial) in order to better calibrate results among different patients, and to acquire more consistent data when imaging a patient serially.

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