Fat Confounds the Observed Apparent Diffusion Coefficient in Patients with Hepatic Steatosis

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Target audience:

Clinicians and researchers with an interest in diffusion weighted imaging (DWI) of the liver.

Purpose:

In the liver, at least 6 distinct fat peaks can be distinguished at clinical field strengths [1]. Several of those peaks (between 4.2 and 5.3 ppm) are close to the water peak and collectively contain approximately 8.7% of the total fat signal. For this reason, water excitation pulses used for fat suppression in conjunction with DWI, even in the absence of Bo inhomogeneities will excite ~8.7% of the trigylceride proton magnetization in tissue. We investigated the dependence of the apparent diffusion coefficient (ADC) on liver fat content and whether it is confounded by fat signal.

Methods:

43 patients underwent liver DWI (b=0,500s/mm^2) and single-voxel MR-spectroscopy (MRS). Proton density fat-fraction (PDFF;range 0.23-34.5%) was measured from MRS. Voxel coordinates from MRS were used to colocalize a region of interest (ROI) in the corresponding location in the right hepatic lobe on ADC maps. In addition, a theoretical model was developed to account for the effects of fat on observed ADC, and used to correct the ADC. Linear correlation analysis and Students t-test were performed to assess the relationship between PDFF and ADC before and after correction.

Results:

Mean PDFF was 2.0 ± 1.2% for the control group (<5.56% liver fat) and 13.5 ± 7.6% for the fatty liver group (p<0.0001). Before correction for fat, the mean ADC was lower for the fatty liver group (1.32 ± 0.3 x 10^{-3}mm^2/s) compared to the control group (1.49 ± 0.25 x 10^{-3}mm^2/s) (p=0.09). Although the ADC of the fatty liver group was lower, the difference was not significant (p=0.09). After correction the difference in mean ADC was not as pronounced for the fatty liver group (1.42 ± 0.31 x 10^{-3}mm^2/s) and the control group (1.50 ± 0.3 x 10^{-3}mm^2/s), with no statistical difference (p=0.51).Linear correlation analysis showed an inverse dependence between observed ADC and PDFF before correction (r^2=0.132;p=0.017), and no dependence after correction (r^2=0.033;p=0.24).

Discussion:

The observed decrease in ADC in fatty liver disease results, at least in part, from the confounding effects of fat. Correction for this confounding factor removes the apparent dependence of the observed ADC on hepatic fat-fraction. DWI in fatty liver disease should therefore be used cautiously, and care must be taken to avoid misinterpretation of observed ADC values in the presence of hepatic steatosis. Further research investigating fat as a confounding factor for accurate ADC measurements is warranted, and methods to mitigate or correct for the effects of fat are needed.

References:

1. Hamilton G, et al. *NMR Biomed* 2011, **24**(7):784-790.

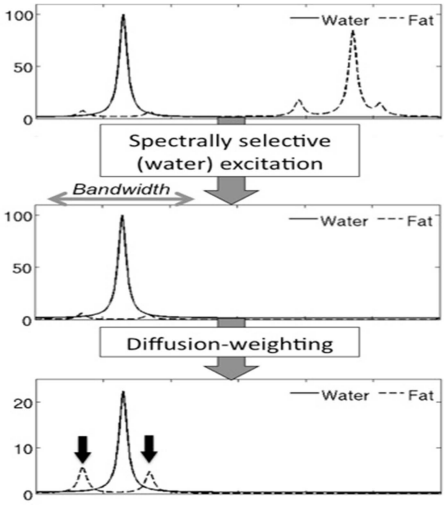

Figure 1. Schematic shows that the relative signal of fat peaks may become significant and introduce large errors in ADC measurement

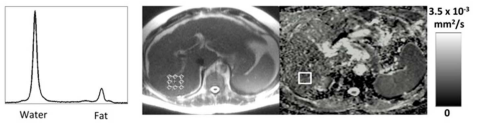

Figure 2. Co-localization of ROI corresponding to the voxel used for MR-Spectroscopy. **Left:** Liver MR spectrum with water and fat peak. **Center:** Localizer shows placement of the MR-Spectroscopy voxel in the right lobe of the liver. **Right:** Corresponding co-localized ROI on ADC-Map

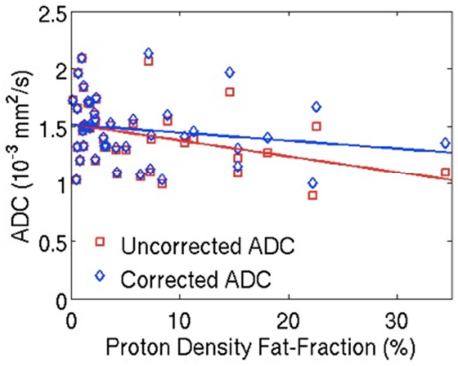

Figure 3. Uncorrected ADC shows a signifcant decrease in the observed ADC with increasing PDFF, with a statistically significant correlation (r^2=0.132; intercept = 1.51 x 10^{-3}mm^2/s (95% confidence interval = 1.40 -1.62 x 10^{-3}mm^2/s), slope = -0.014 x 10^{-3}mm^2/s/PDFF%, (95% confidence interval = -0.025 - -0.003), and p=0.017) After correction for the effects of fat, however, there is no dependence of observed ADC on PDFF (r^2 =0.033; intercept = 1.54 x 10^{-3}mm^2/s (95% confidence interval = 1.40 – 1.62 x 10^{-3}mm^2/s), slope = -0.007 x 10^{-3}mm^2/s/PDFF% (95% confidence interval = -0.019 – 0.005), and p=0.24).