The effect of cardiac phase on liver diffusion tensor imaging (DTI)

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Target Audience: Researcher who is interested in body diffusion.

Purpose: Diffusion weighted imaging (DWI) and the more advanced diffusion tensor imaging (DTI) are well recognized methods to assess microstructural characteristic of tissues. Since the liver has been suggested to be close to isotropic[1], DWI has been a popular choice to diagnosing liver cancer. However, non-zero fractional anisotropy (FA) value has been reported in human[2] and animal studies[3]. It was a result of non-linear liver motion, which produced the apparent diffusion anisotropy, known as pseudo-hepatic artifact[4]. Since the cardiac induced deformation is predominant in the left liver lobe and the amount of deformation changes according to the phase of the cardiac cycle, this should be reflected in the DTI metrics as well.

Material: Liver imaging was done on 5 healthy volunteers using a 1.5T Siemens Espree MRI (Siemens Medical Solution, USA) and a dedicated 16 channel phase array. Five coronal images were acquired with a dual spin echo DTI-EPI sequence (TE/TR = 69/1000ms, slice thickness = 10mm, FOV = 35cm, 110 x 110 matrix, 6/8 partial FFT, 3 individual NEX, about 18s per NEX) at various trigger delay (0, 50, 100, 200, 300, 400, 500 and 600 ms). Motion compensation was done prospectively by a combination of breath holding (at inhalation) and triggering at the peak of the pulse using a pulse oximeter. The average heart rate was recorded for each scan for use in calculating the temporal occurrence of individual cardiac phases. Image post-processing and ROI analysis were done using FSL (FMRIB, Oxford, UK). The calculated fractional anisotropy (FA), mean diffusivity (MD) and eigenvalues (λ_1, λ_2 and λ_3) were evaluated according to the phase of cardiac cycle. A 2-tailed paired Student's t-test was applied to look for statistical significance between the parameters obtained at systole and diastole, on a regional basis (i.e. for either the left or right lobes as shown in ***Figure 1***).

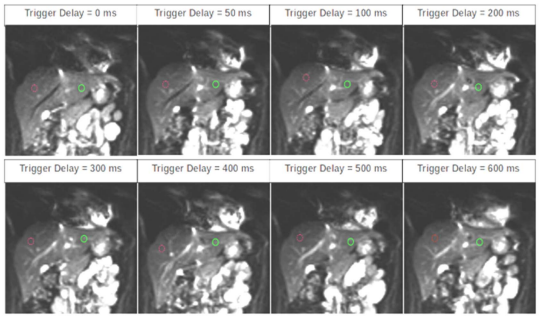

***Figure 1**: Circular ROI selection of the left lobe (green circle) and right lobe (red circle) overlaying on top of the averaged diffusion weighted images at b = 300 mm²/s.*

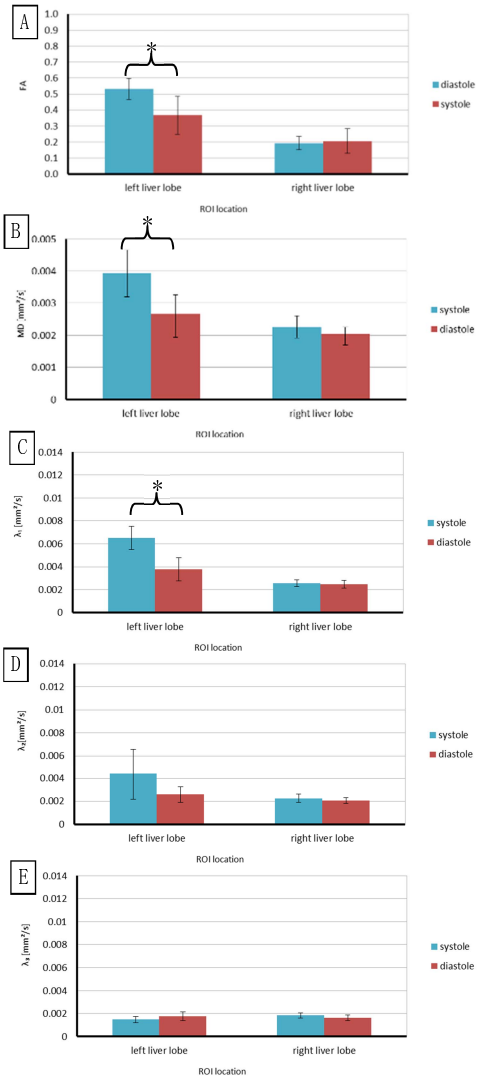

***Figure 2:** A, B, C, D and E correspond to the FA, MD, λ_1, λ_2 and λ_3 plot, which compare the metrics obtained at diastole (red) to systole (blue) at a regional basis. Significant difference was denoted as * (p <0.05).*

Results: As shown in ***Figure 2***, significant increase in FA (0.53±0.07, $p<0.05$), MD (3.9±0.7 x 10^{-3} mm^2/s, $p<0.05$) and λ_1 (6.5±1.0 x 10^{-3} mm^2/s, $p<0.05$) in the left lobe were observed at systole, as compared to the that obtained at diastole (0.37±0.12, 2.7±0.6 x 10^{-3} mm^2/s, 3.8±0.7 x 10^{-3} mm^2/s, respectively). However, no change in FA, MD and eigenvalues in the right lobe were observed between systole and diastole.

Discussion: If the observed change in DT metrics was solely due to motion error, no change should be observed in the left lobe with cardiac triggering applied. Mechanical wave, generated from the cardiac motion, propagates through the liver and lead to non-linear liver deformation. This is, thus, reflected as the change in DT metrics.

Conclusions: Cardiac motion induced non-linear liver motion which leads to significant changes in FA and MD value at the left lobe when compared to right lobe. This suggested that the amount of liver deformation can affect the DT metrics. This artifact was reduced at diastole.

References: [1] Toauli et al. Radiology. 2003; 32 :1141-8 ; [2] Lu et al. Proc. ISMRM. 2010; 18 :4710; [3] Cheung et al. JMRI 2010; 32 :1141-8; [4] Nasu et al. Radiat Med 2006; 24:438-444