Postmortal DWI of the Liver in comparison with in vivo data

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Target Audience

Clinicians, scientists, and attorney dealing with forensic medicine/cases, but also for clinicians who are dealing with liver transplantation.

Introduction/Purpose

Diagnostic radiology has been playing more and more an important role in the forensic medicine in the past decades. It also helps in investigations of mummies and corpses with x-ray or ultra-sound. Magnetic resonance imaging (MRI) was introduced in the forensic medicine as a second line tool, especially for identifying soft tissue injuries. So far, there are few DWI investigations of corpses. The most recent study using DWI (including ADC-Mapping) in post mortem brain seemed to be useful and especially promising in forensic medicine. The purpose of this study was to assess both the changes in water diffusion quantified by diffusion-weighted MR imaging in post mortem liver tissue and to examine the development of the apparent diffusion coefficient (ADC) in the liver after death in comparison to ADC values in vivo tissue.

Material and Methods

Patient population

Twenty-one patients, died of natural cause, were examined (13 male, 8 female; mean age: 70.5 ± 8.7 years; range: 51 – 85 years, mean body weight 74 ± 18 kg). The corpses were stored at room temperature until the scanning. The core temperature was rectally measured throughout the MRI examination. MRI scans were started not later than 6 h post mortem and lasted for 24 h with scan intervals of one hour. To check the comparability of the ADC values a control group of 6 subjects (age: 24 – 67 years) was examined as well. The study protocol was approved by the local Ethics Committee, and informed consent was obtained from all relatives of the dead.

MR Imaging Protocol

All examinations were performed on a 1.5 T MRI scanner (Magnetom Symphony; Siemens Medical Solutions, Erlangen, Germany) with a surface body-coil. For the morphological orientation a localizer as well as HASTE-sequences (TR 1840 ms, TE 125 ms, FoV 350 mm, slice thickness 0.7cm) in transverse, coronal and sagittal orientation were performed.

Diffusion-Weighted Imaging

Based on the HASTE images a diffusion-weighted spin echo echo-planar sequence was generated in transversal orientation: TR 3000 ms; TE 74 ms; FOV 262 x 350 mm; matrix 115 x 2192 mm; slice thickness 6 mm; gap 1.5 mm; voxel size 0.9x0.9x5 mm3; 20 slices, and NEX 10. As a total 2 averages were acquired and scan time was about 4 to 6 minutes summing up to 30 minutes including time for patient positioning and localization of the liver structures.

The ADC is given by the following equation:

$$S(b1) = S(b0)\ \exp(-b1 \bullet ADC)$$

S(b1) is the signal intensity of the image measured with a gradient pulse b1 = 50, 400, and 800 s/mm2 while S(b0) estimates the signal intensity for a b-value of 0 s/mm2. The diffusion-weighting was performed with a trace weighted sequence type (3 orthogonal directions). According to this equation, pixelwise ADC-maps were generated as grey values using the Siemens based software (Syngo MR A30A, Siemens Medical Solutions, Erlangen, Germany).

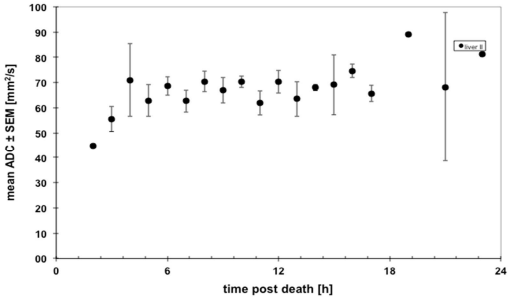
Image and Statistical Analyses

The morphological changes of the liver parenchyma were assessed with the HASTE images. Regions of interest (ROI) of 2.9 ± 0.03 cm2 size were manually drawn on the ADC-maps both right and left liver lobes. Parametric statistics (arithmetic mean value ± standard deviation (SD), SEM, and Student's T-test) was used throughout this work with a significance value of $p < 0.05$ for group differences. In comparisons with our few control subjects (n = 6; age: 24 – 67 years), the more robust discriminatory power test was used.

Results

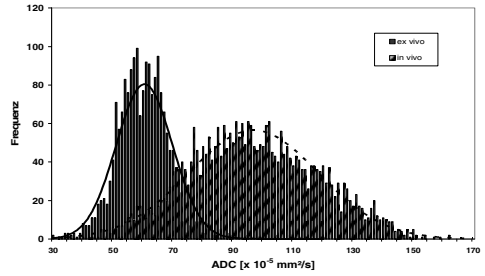
Postmortal Course of ADC

In **Figure 1**, the DWI of the left liver lobe shows an initial increase of the ADC from 44.8 · 10^{-5} mm^2/s (2 h p.m.) to 70.9 · 10^{-5} mm^2/s (4 h p.m.). Five hours post death there is an increase in ADC which reaches a value of 38.3 · 10-5 mm2/s. During the following hours the ADC shows a plateau with an increase at 17 h p.m.. At the end of our examination, there is a maximal increase of the ADC (89.0 x 10^{-5} mm^2/s). In the right liver lobe there is a similar development of the ADC. After an initial increase of the ADC from 35.4 x 10^{-5} mm^2/s to 66.4 x 10^{-5} mm^2/s (4 h p.m.), a slight decrease was seen 66.4 x 10^{-5} mm^2/s (17 h p.m.) before reaching a maximum after 19 hours to 83.4 x 10^{-5} mm^2/s at the end of the examination.



Ex vivo versus in vivo ADC

Furthermore a pixel-wise comparison of the ADC distribution in the region of interest (ROI) between corpses and in vivo patient of the control group was performed. The mean ex vivo ADC in the left liver lobe was 68.6 ± 13.4 · 10^{-5} mm^2/s. The frequency of the ADCs can be described by a Gaussian distribution. The mean in vivo ADC of the thalamus was 111.0 ± 18.8 · 10^{-5} mm^2/s. Figure 2 shows the frequency distribution of the ADCs in ex vivo and in vivo liver with almost no overlap. It could be shown that there are two significantly different normal distributions ($p < 0.001$).



Discussion/Conclusion

It could be shown that ADC values of in vivo and ex vivo human liver differed significantly. Furthermore there is a characteristic postmortal time pattern of ADC after death which might be explained by the same cellular phenomena. With the knowledge of the ex vivo data, DWI may be added to the MRI methods for a virtual autopsy (virtopsy). E. g., temperature effects will cause deviations from the obtained ex vivo data and may give hints to the storage conditions of a corpse after a crime. However, these data could also help to understand and improve organ donation. To improve our understanding of the course of water diffusion, the time immediately after death as well as the reproducibility has to be examined.