Magnetic Resonance Imaging (MRI) with Diffusion Tensor Imaging (DTI) in the evaluation of chronic kidney diseases.

Poster No.: C-1338
Congress: ECR 2012
Type: Scientific Exhibit
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Keywords: Abdomen, Kidney, MR, MR-Diffusion/Perfusion, MR-Functional imaging, Diagnostic procedure, Tissue characterisation
DOI: 10.1594/ecr2012/C-1338

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Purpose

Diffusion Tensor Imaging (DTI) is more useful than DWI in the evaluation of molecular diffusion within the kidney, as it can observe orientation of the diffusion in the space (1).

The analysis of the diffusion maps gives two important parameters: the Apparent Diffusion Coefficient (ADC), which expresses the amount of diffusion, and Fractional Anisotropy (FA), which expresses the preferred direction of diffusion.

The few studies in the literature have shown that molecular diffusion in the kidney is anisotropic, due to the particular structure of the renal parenchyma, where the vessels and tubules are radially oriented, especially in renal medulla (2,3).

Some authors have therefore attempted to differentiate renal cortex and medulla using the values of FA and creating the first tractography reconstructions (3,4).

Different types of chronic kidney diseases can cause structural alterations that lead to renal failure (3,4,5).

The purpose of this study is to detect, using DTI, the changes of the ADC and FA, induced by a spectrum of chronic parenchymal disease, comparing with clinical and laboratory parameters.
methods and materials

1. Study population

- Patient group: fifteen patients with renal failure (7 men and 8 women; mean age 52.3 years; age range, 18-85 years). Renal diseases were: nephroangiosclerosis (n 3, 20%), renal artery stenosis (n 3, 20%), medullary cystic disease (n 3, 20%), diabetic nephropathy (n 1, 7%), pyelonephrites / lithiasis (n 1, 7%), other (n 4, 26%). As co morbidities, hypertension was present in 8 patients (53%) and diabetes mellitus in 4 (26%).

- Control group: 8 patients (3 men and 5 women; mean age 37.7 years; age range, 18-66 years) who did not have kidney disease and underwent an MRI exam of the upper abdomen for other clinical question. No history of renal disease, hypertension, diabetes or other vascular diseases were present.

2. MRI protocol

No specific preparation of the patients, such as fasting or drinking, were needed before MRI exam, that was performed with a 16 channels 1.5T whole-body scanner and a standard phased-array body-coil. In all patients of both groups, the standard MRI protocol according to the specific diagnostic question was performed.

The DTI acquisition was added to the routine clinical protocol in the axial plane, using a breath hold, spin-echo single-shot echo-planar imaging (SSEPI) sequence, with a diffusion gradient along 6 directions and two b-values (0 and 500 sec/mm²). An axial respirator-triggered single-shot fast spin-echo (SSFSE) T2-weighted sequence was acquired to matches the slices of the DTI sequence.

3. Image analysis

- Morphological evaluation:
  - renal dimension (longitudinal diameter and parenchymal thickness);
  - cortico-medullary differentiation (CMD) scored as normal, reduced or absent;

- DTI data analysis:
  - quantitative ADC and FA maps, and tractography were calculated;
  - in all subjects and for each kidney, circular ROIs in two different sites, cortical and medullar, were placed;
• for each ROI, the mean and standard deviation (SD) of the ADC (expressed in $10^{-3} \text{mm}^2/\text{s}$) and FA values were calculated from the ADC and FA maps;
• the tractography, representing preferred pathways of the water diffusion, was calculated starting from these ROIs which were defined as seed-starting points.

4. Statistical analysis

In each subject, in all ROI sites (cortical and medullar) the mean value of ADC and FA between left and right kidney was calculated.

Two-tailed unpaired Student's $t$ test was used to compare the mean values of ADC and FA, for each ROI site, in each group and between the two groups.

A $p$ value of less than 0.05 was considered to indicate a statistically significant difference.
Results

No major distortion artifacts were observed in the DTI images of all patients.

In control group, renal dimension and CMD were judged normal in all cases.

In patient group, the results of morphological evaluation were the followings: 1. longitudinal diameter was bilateral normal in 10/15, bilateral reduced in 2/15, unilateral reduced in 3/15; 2. parenchymal thickness was bilateral normal in 9/15, bilateral reduced 3/15, unilateral reduced 3/15; 3. CMD was bilateral normal in 7/15, bilateral reduced in 5/15, unilateral reduced in 3/15.

Differentiation between cortex and medulla in the DTI b0 images was possible in all patients.

The results of t-test analysis of ADC and FA were shown in the Table 1. In the control group, ADC value was significantly higher in the cortex than in the medulla; FA value was significantly higher in the medulla than in the cortex (p<0.05), according to literature data. In the patient group, the same difference between cortical and medullar ADC was present, but no statistically significant difference was found between cortical and medullar FA. The comparison between the two groups showed that FA value in the medulla was significantly lower (p<0.05) in the patient group than in the control group; there was no significant difference for the other parameters.

In patients of the control group, the tractography, calculated starting from the FA map, showed regular arrangement of the lines, which assume radial orientation, in the medulla (Fig. 1), whereas, in patients with impaired renal function, disruption of this organization was present (Fig. 2).
Table 1 – Mean values and SD of ADC and FA between left and right kidney in each group. Statistically significant difference between the two groups is present only for medullar FA value.

<table>
<thead>
<tr>
<th></th>
<th>ADC (x10^-3 mm^2/sec)</th>
<th>FA</th>
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<tbody>
<tr>
<td></td>
<td>Cortex</td>
<td>Medulla</td>
</tr>
<tr>
<td>Control group</td>
<td>2.53±0.16</td>
<td>2.22±0.20</td>
</tr>
<tr>
<td>Patient group</td>
<td>2.52±0.37</td>
<td>2.29±0.30</td>
</tr>
</tbody>
</table>

Table 1

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Figure 1 – (a) DTI b0 image; (b) ADC map; (c) FA map; (d) Tractography. DTI analysis of the right kidney in a patient of the control group: circular ROIs placed in cortical and medullar sites with corresponding ADC (b) and FA (c) values. Tractography reconstruction (d) shows regular arrangement of the lines.

Fig. 1

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Figure 2 – (a) ADC map; (b) FA map; (c e d) Tractography. DTI analysis of both kidneys in a patient with medullary cystic disease: medullar FA value is reduced (b); corresponding tractography reconstructions (c e d) show disruption of spatial orientation of the lines.

Fig. 2

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Conclusion

The DTI could be a useful tool in the evaluation of chronic kidney disease and, in particular, the medullar FA is the main parameter for the assessment of renal damage.
References


