Evaluation of the feasibility and reproducibility of renal DTI MRI in healthy volunteers

M. Cutajar[1], S. D. Marks[1], J. D. Clayden[1], C. A. Clark[1], and I. Gordon[1]

[1]Radiology and Physics, UCL Institute of Child Health, London, London, United Kingdom

Purpose: Diffusion Tensor Imaging (DTI) provides structural parameters relatively unstudied in the kidney, the Apparent Diffusion Coefficient (ADC) and the Fractional Anisotropy (FA). The ADC gives an indication of the overall extent of diffusion, while the FA characterises the directionality of water diffusion in the tissue of interest. Initial studies have found a clear difference between the renal cortex and medulla for both ADC and FA values. The aim of this study was to determine the reproducibility and robustness of this technique to justify the utility of this method in the clinical environment.

Materials and Methods: The local ethics committee approved the study protocol. Seven healthy volunteers (age range, 24 – 31 years), were imaged twice on different days. In addition, two of the seven volunteers were also imaged 5 times on the same scanning session to test for reproducibility over a day.

Oblique-coronal diffusion tensor imaging (DTI) data volumes for all volunteers were acquired on a 1.5 T Siemens Avanto scanner (Siemens Medical Solutions, Erlangen, Germany) with a dedicated abdominal TIM 32 channel body phased array coil. The body matrix and six elements of the inbuilt spine matrix were used for signal reception. DTI (Figure 1) was performed using a coronal multi-section echo-planar sequence; six slices, 5-mm thick sections with no gap, diffusion sensitisation along 20 non-collinear directions, TR/TE = 730/73 ms and 2 *b*-values (0 and 400 s mm^{-1}). Volunteers were asked to hold their breath throughout the data acquisition (approx 20 s).

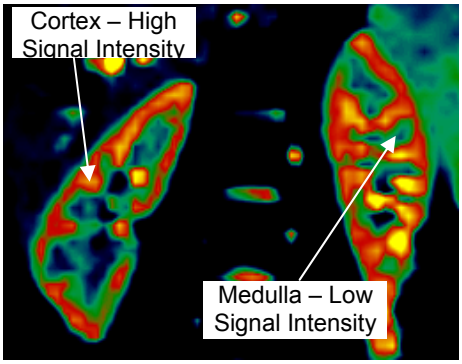

Figure 1: B = 0 image.

Several regions of interest encapsulating cortical and medullary regions were selected using the analytical package MIStar (Apollo Medical Imaging, Melbourne, Australia). From each of the regions an ADC and FA value was obtained. An average of these values was obtained so as to produce one ADC and one FA value for the cortical part of the kidney and another for the medullary part.

Results and Conclusion: The ADC value in the cortex is always larger than that in the medulla, on the other hand, FA in the cortex is always less than that of the medulla in healthy volunteers.

Reproducibility over one day – The mean of the 5 repeats was calculated for each cortex and medulla (4 kidneys in total). The average ADC = 270.5 ($\pm$ 10.6) $\times$ 10^{-5} mm^2 s^{-1} for the cortex, and 231.2 ($\pm$ 10.7) $\times$ 10^{-5} mm^2 s^{-1} for the medullary regions, with a coefficient of variation (CV) = 5.8 and 4.5 % respectively, which implies that minimal variation was found between the 5 repeats carried on the same two volunteers on the same scanning session.

Reproducibility over a month – DTI in volunteers imaged twice (N = 7), showed mean ($\pm$ SD) cortical ADC = 258.5 ($\pm$ 15.8) $\times$ 10^{-5} $\pm$ 15.8 mm^2 s^{-1} (CV = 6 %) and mean medulla ADC = 214.7 ($\pm$ 19.5) $\times$ 10^{-5} mm^2 s^{-1} (CV = 9 %). Reproducibility within individuals using a paired t-test to compare scans performed on the same person on two different days gave p-values = 0.192 and 0.505 for the cortical and medullary regions respectively, showing good reproducibility. The same DTI images were used to produce FA maps (Figure 2) from which FA values were extracted: cortex = 0.22 $\pm$ 0.03 and medulla = 0.31 $\pm$ 0.04, CV = 15 and 13 % respectively. No significant difference was found between the 1st and 2nd scan undergone by the volunteers (p-values = 0.244 and 0.470 for the cortical and medullary regions respectively). These preliminary studies show that MRI parameters are reproducible, implying that they are reliable biomarkers. These methods provide information about the renal ultrastructure and may potentially be used for early detection of renal injury and therefore allow tailoring of clinical intervention.

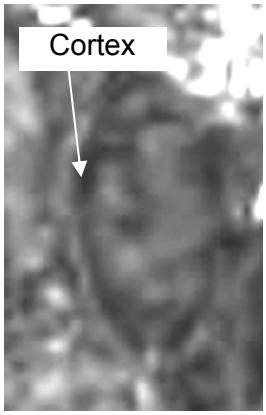

Figure 2: FA map of a kidney. The cortex appears dark on this image, indicating that water diffusion is relatively isotropic (undirected) in this region.

References:

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2. Notohamiprodjo M, Glaser C, Herrmann KA, et al. Diffusion tensor imaging of the kidney with parallel imaging: initial clinical experience. Invest Radiol 2008;43(10):677-85.