Evaluation of Renal Function with Diffusion Weighted MRI of the Kidneys

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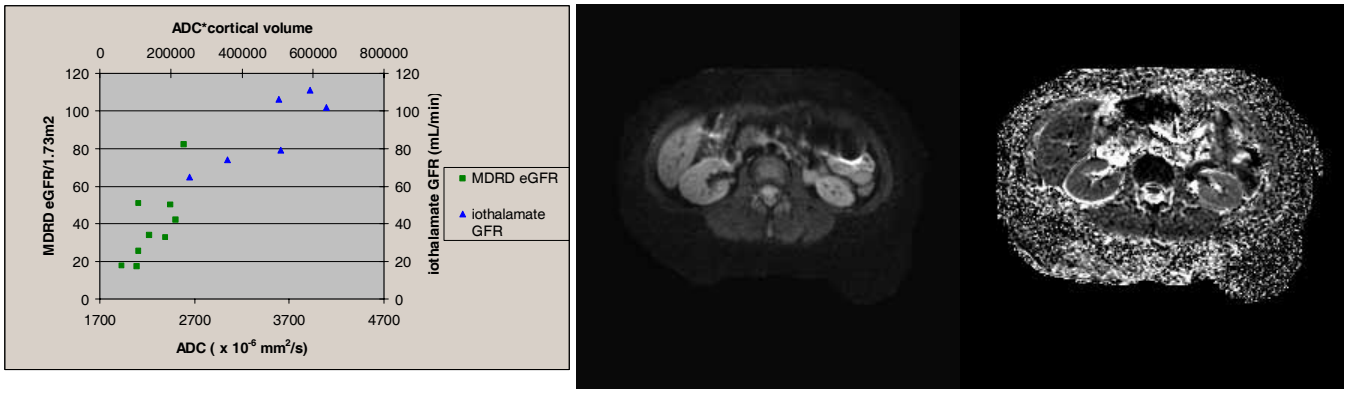
Introduction: In recent years diffusion weighted MRI (DWI) has begun to be applied outside of the central nervous system, with researchers examining DWI of the abdominal and pelvic organs. Initial studies of DWI in the kidneys [1-3] have shown a relationship between the apparent diffusion coefficient (ADC) in renal parenchyma and renal function, with scan subjects with elevated serum creatinine (Cr) generally having lower renal ADC values than subjects with normal renal function. One significant limitation of these studies has been the lack of gold standard measurements of renal function (inulin or iothalamate clearance) in the subjects. Serum creatinine is affected by factors other than glomerular filtration rate (GFR), such as muscle mass, and predictive equations based on Cr such as the Cockroft-Gault equation or the Modification of Diet in Renal Disease (MDRD) equation are known to correlate somewhat poorly with GFR [4,5]. Additionally, differences in technique among these early studies have limited evaluation of the exact relationship between GFR and renal ADC. In order to accurately assess the relationship between renal function and renal DWI it is necessary to have accurate measurements of GFR in patients getting diffusion weighted MRI, preferably on the same day, as GFR is known to fluctuate up to 10% in normal individuals. We hypothesize that renal cortical ADC provides an accurate measure of the function of renal cortex, so that the product of cortical ADC and renal cortical volume is proportional to GFR. This may provide a simple, rapid, non-invasive method of accurately measuring renal function.

Methods: All procedures were approved by the Stanford University institutional review board. Initial evaluation of the MR technique was performed in 9 hospitalized patients with moderate chronic kidney disease. Breath-held DWI was performed in these patients on 1.5T commercially available MRI units (Signa CV/I and TwinSpeed, GE Medical Systems, Waukesha, WI) using the body coil. Single-shot spin-echo echo-planar imaging (ssEPI) sequences were performed, with TR 2600-3200ms, TE 45.3-55.1ms, matrix 128x128, bandwidth +/- 125kHz, FOV 30cm x 30cm to 40cm x 40cm. b-values were 0 and 300 s/mm^2. Tetrahedral encoding was used, and trace maps of the diffusion tensor <D> were generated. Average values of Tr<D> were computed by taking several regions of interest (ROIs) in the renal parenchyma, and the results were compared with GFR estimated from the MDRD equation (eGFR). Following this initial validation, 6 living renal donors or donor candidates were studied, both with DWI and with same day iothalamate clearance. In these subjects DWI scans were obtained with higher resolution (192x128 matrix with 0.7 phase FOV) and TR 2100ms in all subjects. b-values were again 0 and 300 s/mm^2, although the effect of higher b-values is also currently being investigated. These scans were also performed on a 1.5T GE MRI unit, however a 4 channel phased array coil was employed. Additionally, renal cortical volume (CV) was measured in these patients using post-gadolinium cortico-medullary phase 3D SPGR MRI, using the technique described previously [6]. For this portion of the study, 0.3mmol/kg Gd-DTPA (to a maximum of 40cc) was injected at 2cc/s, following a 2cc timing bolus. The parameters used were: 512x384 matrix, 2.4mm slice thickness (coronal) every 1.2mm, parallel imaging with acceleration factor of 2, and scan times 20-25s. The product of CV and ADC was computed and compared with GFR.

Results:



(a) *(b)* *(c)*

Figure 1. (a) GFR vs. renal ADC. Green squares represent hospital subjects with chronic kidney disease. In these patients no post-contrast images were available and GFR was estimated from the MDRD equation. Blue triangles represent transplant donors or potential donors. In these subjects GFR was measured directly, and cortical volume was also measured using post-contrast MRI. (b) diffusion-weighted image in a transplant donor candidate (c) ADC map from the same image.

In the initial validation study in patients with chronic renal disease, there was a fair linear correlation between MDRD eGFR and ADC (R^2 = 0.56, p=0.021). There was very good linear correlation between actual GFR measured with iothalamate clearance and ADCxCV among the transplant donors (R^2=0.73, p=0.029).

Conclusions: The data show very good correlation between renal ADC x cortical volume and GFR, indicating that DWI shows substantial promise for noninvasive evaluation of renal function. DWI is simple to perform and adds only a single 20s-30s sequence to standard renal MRI. More data are needed to confirm these results, particularly in other patient populations.

References:

[1] Thoeny et al., Radiology, v235, p911 (2005)
[2] Namimoto et al., JMRI, v9, p832 (1999)
[3] Fukuda et al., JMRI, v11, p156 (2000)
[4] Froissart et al., J Am Soc Neph, v16, p763 (2005)
[5] Rule et al., Am J Kid Disease, v43, p112 (2004)
[6] Coulam et al., JMRI, v15, p174, (2002)

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