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Diffusion weighted (DW) MRI in assessment of renal function - a preliminary study to determine the Apparent Diffusion Coefficient (ADC) values of kidneys with normal function

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Abstract
Aim: *To determine the ADC values of kidneys in patients with normal serum creatinine values as an initial step to investigate the clinical potential of diffusion-weighted imaging (DWI) in assessing renal function in comparison with serum markers of renal function.*
Materials and Methods: *MR imaging is performed on 1.5 Tesla MR machine (Siemens) Diffusion weighted images are obtained at b values 0, 50. 400 and 800. Using automated ROI delineation methods ADC values are measured in the upper pole, interpolar region and lower pole of both kidneys. The mean ADC values were recorded for each kidney for each patient is recorded. The patients selected for this study had normal values for serum markers of renal function.*
Results: *The ADC value for renal parenchyma varied from $1.697x\ 10^{-3}mm^2/s$ to $1.948x10^{-3}mm^2/s$ with a mean ADC value of kidneys ranging from $1.730x10^{-3}mm^2/s$ to $1.885x10^{-3}mm^2/s$*
Conclusion: *Diffusion weighted MR imaging of the kidney can be useful imaging modality in the early determination of renal parenchymal disease especially with unilateral dysfunction. ADC values may predict abnormality earlier than serum markers of renal function.*
Keywords: *Renal parenchymal disease, diffusion weighted imaging (DWI), apparent diffusion coefficient (ADC). estimated glomerular filtration rate (eGFR).*

Introduction

The kidney is a particularly interesting organ to study with DW MR imaging techniques because of its high blood flow and water transport functions. The pathologic changes will restrict the free movement of water molecules in the extracellular extravascular space and can cause a decrease in apparent diffusion coefficient (ADC) values. Patients with chronic kidney disease had significantly lower renal ADC values and that there was a negative correlation between the ADC and serum creatinine level in patients with chronic renal failure.[(1)]

The study aims at determining the ADC values in kidneys at different stages of renal dysfunction and in a normal population. This can be a standard in the early determination of unilateral renal dysfunction even when the serum creatinine levels are normal. The present study is to try to establish the cut off values for ADC in normal functioning kidneys.

Materials & Methods (Methodology)

After obtaining the clearance from the Instituitional Research committee and Instituitional Ethical committee, the study was conducted at Dept. of Radiodiagnosis, Medical College, Trivandrum. Adult patients who undergo magnetic resonance imaging of the abdomen for various clinical reasons and with normal serum markers for renal function were the subjects for the study.

All data including demographic information, clinical, and laboratory findings were obtained from the medical records of the patients.

The serum creatinine levels are obtained by standard laboratory assay. eGFR is calculated using MDRD equation -

MR imaging is performed on 1.5 Tesla MR machine (Siemens). Diffusion weighted images in the axial plane are taken for calculation of ADC .Diffusion weighted images are obtained at b values 0, 50. 400 and 800. Using automated ROI delineation methods for measurement of ADC values, region of interest (ROI) is placed on the renal parenchyma without any preference for cortex or medulla. Three circular ROIs of 1 cm2 are placed-one each in the upper pole, interpolar region and lower pole of both kidneys. The mean ADC values were recorded for each kidney.

Three subjects with normal serum markers of renal function were the subjects for this preliminary study. Their e GFR was calculated using MDRD equation. These patients had a serum creatinine value less than 1, they had no known history of renal parenchymal disease, had normal echogenicity on sonography and eGFR of less than 90 mL/min/1.73 $m^{2.}$

Results

The ADC value of renal parenchyma at various levels varied from $1.697x10^{-3}mm^2/s$ to $1.948x10^{-3}mm^2/s$. The average ADC value of kidney varied from $1.730x10^{-3}mm^2/s$ to $1.885x10^{-3}mm^2/s$

Table 1- Measurements of ADC of renal parenchyma

	Upper pole	Interpolar	Lower pole	Mean
Case 1 RK	1.832	1. 870	1. 875	1.859
LK	1.792	1.760	1.744	1.765
Case2 RK	1.759	1.712	1.871	1.781
LK	1.754	1.739	1.697	1.730
Case 3 RK	1.708	1..881	1.749	1.779
LK	1.948	1.889	1.819	1.885

Discussion

Chronic kidney disease (CKD) is a common global health problem and its average incidence is on the rise with the increase in incidence of hypertension and diabetes. Serum creatinine, and estimated glomerular filtration rate (eGFR) are indirect biochemical tests for assessing renal filtration , however they are imperfect and cannot assess unilateral renal function.

Diffusion weighted MRI is an evolving field and its potential is yet to be fully utilised.

DW MRI is a noninvasive modality to characterise tissues based on Brownian motion of water molecules within them. Apparent diffusion coefficient (ADC) is a quantitative parameter calculated from DWI that combine the effects of capillary perfusion and water diffusion .The pathologic changes will restrict the free movement of water molecules in the extracellular extravascular space. This cause a decrease in apparent diffusion coefficient (ADC) values.

Kidney is an organ with high blood flow and water transport functions.Preliminary research has shown that patients with chronic kidney disease had significantly lower renal ADC values .There was a negative correlation between the ADC and serum creatinine level in patients with chronic renal failure.

eGFR is calculated using Modification of Diet in Renal diseases (MDRD) equation -

$$eGFR = 186 \times (Creat / 88.4)^{-1.154} \times (Age)^{-0.203} \times (0.742 \text{ if female})$$

Chronic kidney disease (CKD) is graded into five stages based on disease severity, according to the K/DOQI (kidney disease outcomes quality initiative) CKD classification.

Stage 1: eGFR; ≥90 mL/min/1.73 m^2 (kidney damage with normal or increased eGFR).

Stage 2: eGFR; 60–89 mL/min/1.73 m^2 (kidney damage with a mild reduction in eGFR).

Stage 3: eGFR; 30–59 mL/min/1.73 m^2 (moderate reduction in eGFR).

Stage 4: eGFR; 15–29 mL/min/1.73 m^2 (severe reduction in eGFR).

Stage 5: eGFR; < 15 mL/min/1.73 m^2 (kidney failure).

Various studies indicate there is a relation between the ADC values and eGFR.

In a study published in the European Journal of Radiology [(1)] on 110 patients with CKD , ADC values ranged between 0.839 and 1.508 (x 10 $^{-3}$ mm^2 /s) In a study published in the Indian Journal of Radiology and Imaging Goyal, et al.[(2)] reported that the mean ADC values of different stages of CKD were significantly different from each other and showed a decreasing trend with increasing stage using *b*-values ranging between 0 and 500 s/mm^2.

Normal renal function involves multiple processes of water transport, while worsening renal function (reduction in GFR) should lead to a decrease in water reabsorption, i.e. a lower rate of water transfer across interstitial space. This would potentially reduce diffusion. In addition, fibrosis formed in the process of chronic renal dysfunction may also restrict water diffusion.

Conclusion

The present study in normally functioning kidneys showed the ADC value of kidneys to range from 1.730x10^{-3}mm^2/s to 1.885x10^{-3}mm^2/s. A decrease in renal function due to fibrosis will lower the ADC values and there could be a correlation between the various stages of renal parenchymal disease and decreasing ADC values.

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