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Research article

Combination of renal apparent diffusion coefficient and renal parenchymal volume for better assessment of split renal function in chronic kidney disease

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ABSTRACT

Objective: To investigate the value of the combination of the split renal apparent diffusion coefficient (ADC) and renal parenchyma volume (RPV) by diffusion-weighted imaging (DWI) for assessment of split renal function in patients with chronic kidney disease (CKD).

Methods: Forty-eight eligible participants (36 CKD patients and 12 healthy individuals) were included in the study. All of them underwent DWI (b = 0 and 800 s/mm^2) examination with a 1.5 T MRI scanner to determine the split renal ADC and RPV. Glomerular filtration rate (GFR) was measured by 99Tcm-DTPA scintigraphy using Gates' method and used as the reference standard. All statistical tests were performed using SPSS 20.0 and MedCalc 10.0 statistical software packages.

Results: Split renal ADC, RPV, and their product were significantly correlated with GFR ($\gamma = 0.493$, $p < 0.0001$; $\gamma = 0.337$, $p = 0.018$; $\gamma = 0.708$, $p < 0.0001$, respectively). The product of split renal ADC and RPV had a significantly higher correlation with GFR ($\gamma = 0.708$) than split renal ADC ($p = 0.0002$) and RPV ($p = 0.016$). ROC curve analysis showed that the product of split renal ADC and RPV was a significantly better indicator of reduced split renal function (AUC = 0.893) compared to split renal ADC ($p = 0.0455$) and RPV ($p = 0.0326$).

Conclusion: The combination of split renal ADC and RPV obtained by DWI can significantly improve the assessment of split renal function in CKD patients.

1. Introduction

With the aging of the global population and changes in lifestyle and dietary habits, the morbidity and mortality rates of chronic kidney disease (CKD) have increased rapidly. Epidemiological studies suggest that CKD has become a major threat to health worldwide [1,2]. In addition, CKD is a life-long disease. If not controlled well, the kidney damage will be aggravated gradually, resulting in declining kidney function and eventually uremia [3]. Present clinical treatment strategies focus on halting the progression of CKD, which requires accurate monitoring of renal function during life-long follow-up of CKD patients.

Currently, many methods are available for estimating renal excretory function in clinical practice and in research, and each has some disadvantages. As creatinine is a waste product in the bloodstream that must be removed by the kidney, determination of plasma creatinine levels and creatinine clearance are the most common methods for estimating the glomerular filtration rate (GFR). However, creatinine clearance tends to overestimate the true GFR due to tubular secretion of creatinine. Such error reduces the sensitivity for early detection of decreased renal function [4]. Also, creatinine clearance reflects the gross renal function, limiting the specificity of split renal function assessment. GFR measurement by radioisotopic methods is considered the standard for assessing split renal function. However, its clinical use is limited due to disadvantages such as the use of radioactive tracers, the low spatial resolution of images, long examination time, and operator dependence [5]. Therefore, it is imperative to develop a non-invasive imaging modality for effective follow-up of renal function in CKD patients.

Diffusion-weighted imaging (DWI) is a non-invasive magnetic resonance imaging (MRI) method that is specifically sensitive to water

Abbreviations: CKD, chronic kidney disease; GFR, glomerular filtration rate; DWI, diffusion-weighted imaging; ADC, apparent diffusion coefficient; RPV, renal parenchymal volume; ROI, region of interest; ROC, receiver operating characteristic; AUC, area under the curve; ACR, albumin to creatinine ratio; D, diffusion coefficient

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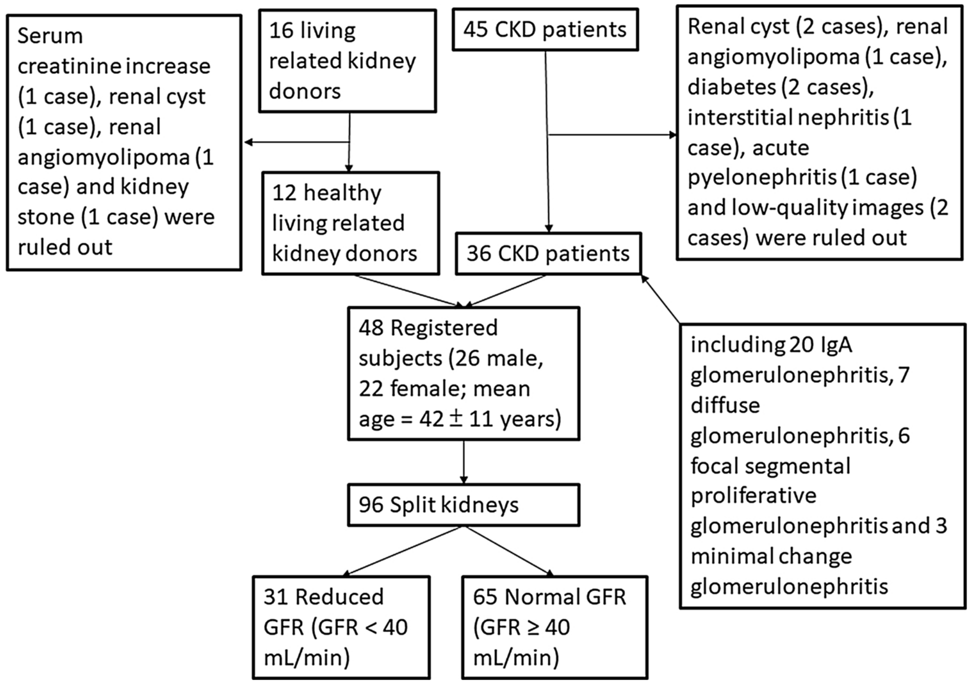

Fig. 1. Flowchart for subject inclusion.

Table 1
Basic Clinical Characteristics of Subjects.

Characteristic	Healthy volunteers		CKD patients	
No. of subjects	12		36	
Men	5		21	
Women	7		15	
Age	40.9 ± 9.5		39.6 ± 7.4	
Serum creatinine concentration (μmol/L)	75.1 ± 19.4		135.8 ± 43.3	
GFR (mL/min)				
Total	113.6 ± 25.3		63.3 ± 13.5	
Left kidney	58.9 ± 11.9		30.0 ± 6.2	
Right kidney	59.8 ± 13.8		34.9 ± 11.8	
Number of split kidney	Left kidney: 12	Right kidney: 12	Left kidney: 36	Right kidney: 36
Number of split kidney (GFR ≥40 mL/min)	12	12	22	19
Number of split kidney (GFR < 40 mL/min)	0	0	14	17

Note—Data are number or mean ± SD. GFR = glomerular filtration rate.

Table 2
Diffusion-weighted MRI parameters.

Parameter	PACE-DWI (b = 0, 800 s/mm^2)
TR (ms)	1300
TE (ms)	82
No. of excitations	2
Matrix	192 × 192
FOV (mm)	360 × 360
Slice thickness (mm)	5
Slice gap (mm)	1.5
Bandwidth (Hz)	1736
Generalized autocalibrating partially parallel acquisitions	2
Fat-suppression	Frequency selective saturation
Average sampling time (s)	77

Fig. 2. The renal parenchyma ROI on DWI image was manually delineated and overlaid to corresponding ADC map.