Diffusion tensor imaging findings diagnosis for patients with chronic kidney disease

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Abstract

Background Chronic kidney disease (CKD) can lead to systemic inflammatory responses and other cardiovascular disease. Diffusion tensor imaging findings generated by gadolinium-based MRI (DTI-GBMRI) is regarded as a standard method for assessing the pathology of CKD. To evaluate the diagnostic value of DTI-MRI for renal histopathology and renal efficiency, renal fibrosis and damage, noninvasive quantification of renal blood flow (RBF) were investigated in patients with CKD.

Methods CKD patients ($n = 186$) were recruited and underwent diagnosis of renal DTI-GBMRI or DTI-MRI to identify the pathological characteristics and depict renal efficiency. The cortical RBFs and estimated glomerular filtration rate (eGFR) were compared in CKD patients undergone DTI-GBMRI ($n=92$) or DTI-MRI ($n=94$).

Results Results showed that gadolinium enhanced the diagnosis generated by DTI-MRI in renal fibrosis, renal damage and eGFR. The superiority in sensitivity and accuracy of DTI-GBMRI method in assessing renal function and evaluating renal impairment was observed in CKD patients compared with DTI-MRI. Outcomes demonstrated that DTI-GBMRI had higher accuracy, sensitivity and specificity than DTI-MRI in diagnosing patients with CKD.

Conclusions In conclusion, these outcomes indicate that DTI-GBMRI is a potential noninvasive method for measuring renal function, which can provide valuable information for clinical CKD diagnosis (Trial registration number: ChiCTR-IPR-16010073, 02/12/2016, registered status).

Background

Chronic kidney disease (CKD) is a public health problem worldwide, which is a gradual impairment of renal function (1). Patients with CKD are at increased risk of cardiovascular disease other chronic conditions with their daily lives (2). Clinically, CKD is characterized by a low estimated glomerular filtration rate (eGFR, $< 60 \text{ mL/min/1.73 m}^2$), which may progress at varying rates depending on blood pressure (BP) management, history of decreased GFR, level of proteinuria (3). CKD may result in abnormalities of multiple physiological processes including removal of waste products of metabolism, heterogeneous disorders on kidney structure and function, electrolyte balance that substantially increases mortality risk due to atherosclerotic cardiovascular disease (ASCVD) (4). Therefore, CKD patients require imaging monitoring to accurately predict risk of declining renal function and guide therapeutic schedules.

CKD is generally diagnosed by imaging of the kidney using ultrasonography (US), contrast-enhanced ultrasound (CEUS), computed tomography (CT), or magnetic resonance imaging (MRI) (5).

Cardiovascular magnetic resonance (CMR) is a standard method for imaging impairment in kidney function, renal injury and fibrosis (6). MRI technique in particular has the potential to present both structural and functional parameters in the kidney by using targeted magnetic nanoparticles (7).

Gadolinium (GB)-based contrast agents are frequently used to enhance the diagnostic efficacy of MRI in patients with kidney diseases (8). A potential alternative imaging modality for evaluating GFR and renal

fibrosis is diffusion tensor imaging findings generated by Gadolinium-based MRI (DTI-GBMRI) (9). Thus, DTI-GBMRI may be ideal for renal function assessment in patients with CKD.

This purpose of this study was to comprehensively assess renal histopathology and renal efficiency, renal fibrosis and damage, noninvasive quantification of renal blood flow in patients with CKD using DTI-GBMRI. The sensitivity and accuracy between DTI-GBMRI and DTI-MRI method in assessing renal function and evaluating renal impairment was compared in CKD patients. The association between RBF value and eGFR was analyzed in patients with CKD.

Methods

Patients

A total of 186 CKD patients were recruited in Hongqi Hospital Affiliated To Mudanjiang Medcial University between January 2017 and May 2019. The inclusion criteria were as follows: (1) age > 18 years; (2) Stage 1 of CKD ($\text{eGFR} \geq 90 \text{ ml/min/1.73 m}^2$); Stage 2 of CKD ($60 \text{ ml/min/1.73 m}^2 \leq \text{eGFR} < 90 \text{ ml/min/1.73 m}^2$); The exclusion criteria were as follows: (1) patients with HIV infection, polycystic kidney disease, cancer; (2) patients with transplant recipients; (3) pregnant and breastfeeding women; (4) history of adverse reaction to gadolinium. The protocol was approved by the ethics committee of Hongqi Hospital Affiliated To Mudanjiang Medcial University. CKD patients received DTI-GBMRI ($n = 92$) or DTI-MRI ($n = 94$) diagnosis. All participants signed written informed consent.

Results

Characteristic of patients with CKD

A total of 186 CKD patients were enrolled in this study. All CKD patients in stage 1 or 2 were enrolled between May 2017 and June 2019. A flowchart of CKD patient recruitment is shown in Fig. 1. The age of CKD patients was 46.5 years old (range, 30–65 years). CKD patients voluntarily received DTI-GBMRI ($n = 92$) or DTI-MRI ($n = 94$) diagnosis. Table 1 shows the demographics and characteristics of patients with CKD. There were no significant differences in BMI, age, sex, blood pressure, cerebrovascular disease, and intraocular pressure between two groups. Signalment and renal biomarkers in two groups were not significant difference.

Table 1
Characteristic of CKD patients

	DTI-MRI	DTI-GBMRI
Number	94	92
Male/female	54/40	53/39
Age (years)	52 ± 10	52 ± 10
BMI (Kg/m ²)	25.2 ± 2.6	25.8 ± 3.1
Blood pressure (mm Hg)		
Systolic	132.3 ± 8.5	130.8 ± 9.0
Diastolic	82.6 ± 5.8	84.2 ± 6.5
Cerebrovascular disease	10 (10.6%)	9 (9.8%)
Intraocular pressure (mm Hg)	14.5 ± 2.6	14.8 ± 3.1
Smoking, n (%)	10 (10.6%)	10 (10.9%)
CKD stages		
2 (mild)	50 (53.2%)	50 (54.3%)
3a (mild to moderate)	44 (46.8%)	42 (45.7%)
Data are expressed as mean ± or n (%). The <i>P</i> values were calculated via independent sample <i>t</i> test for continuous variables and chi-square test for categorical variables. BMI, body mass index; CKD, chronic kidney disease.		

The pathological characteristics and depict renal efficiency diagnosed by DTI-GBMRI

We compared the pathological characteristics and depict renal efficiency in CKD patients diagnosed by DTI-GBMRI or DTI-MRI. CKD patients diagnosed by DTI-GBMRI showed more renal vascular lesions and bigger diameters of lesions than those patients in DTI-MRI group. The average diameter diagnosed by DTI-GBMRI was 3.28 cm, while was in 3.02 cm in CKD patients diagnosed by DTI-MRI. DTI-GBMRI had significantly better performance than DTI-MRI in measuring lumen depiction scores (4.8 ± 0.2 vs 3.2 ± 0.2 for arterial inflow, 4.2 ± 0.1 vs 1.8 ± 0.2 for arterial outflow, 3.8 ± 0.3 vs 2.0 ± 0.3 for anastomosis, and 4.4 ± 0.2 vs 2.2 ± 0.2 for venous outflow; $P < 0.01$), intraluminal signal homogeneity (0.24 ± 0.03 vs 0.40 ± 0.05 , $P < 0.01$), and CNR efficiency in the venous outflow (5.2 ± 0.3 vs 2.6 ± 0.3 , $P < 0.01$) (Table 2).

Table 2
The pathological characteristics and depict renal efficiency diagnosed by DTI-GBMRI

	DTI-MRI	DTI-GBMRI	P value
Diameters of lesions (cm)	3.02 ± 0.32	3.28 ± 0.24	0.0045
Depiction scores	3.2 ± 0.2	4.8 ± 0.2	0.0032
Arterial inflow	1.8 ± 0.2	4.2 ± 0.1	0.0010
Arterial outflow	2.0 ± 0.3	3.8 ± 0.3	0.0041
Venous outflow	2.2 ± 0.2	4.4 ± 0.2	0.0036
Intraluminal signal homogeneity	0.40 ± 0.05	0.24 ± 0.03	0.0057
CNR efficiency	2.6 ± 0.3	5.2 ± 0.3	0.0028
Data are reported as mean ± SD. The <i>p</i> values were analyzed using independent sample <i>t</i> test.			

Kidney volume and functional parameters estimates

Kidney volumes and functional parameters estimates were compared in CDK patients between DTI-GBMRI and DTI-MRI groups (Table 3). The mean kidney volumes of CDK patients in DTI-GBMRI and DTI-MRI were 2046 ± 214 ml and 1868 ± 224 ml, respectively ($p < 0.01$). Creatinine levels were not significantly different between DTI-GBMRI and DTI-MRI groups. The total glomerular count in CKD patients diagnosed by DTI-GBMRI and DTI-MRI was around 16320 ± 12350 and 14560 ± 10180 , respectively ($p < 0.01$). MTT_K was significantly higher in the DTI-MRI group (186.2 ± 40.5 seconds) than in the DTI-GBMRI group (137.6 ± 30.6 seconds). DTI-GBMRI revealed stronger impairment of renal perfusion (156 ± 7 vs 293 ± 44 mL/[min $\times$ 100 g]; $P < 0.01$) and more pronounced increases in T2 (60.1 ± 2.0 vs 45.7 ± 1.2 milliseconds, $P < 0.01$) and T1 relaxation times (1938 ± 53 vs 1350 ± 27 milliseconds, $P < 0.01$) than DTI-MRI. Apparent diffusion coefficient was $1.39 \pm 0.14 \times 10^{-3}$ mm²/s and $1.83 \pm 0.05 \times 10^{-3}$ mm²/s in kidneys in DTI-GBMRI group and DTI-MRI group, respectively ($P < 0.05$).

Table 3
Kidney volume and functional parameters estimates diagnosed by DTI-GBMRI

	DTI-MRI	DTI-GBMRI	P value
kidney volumes (ml)	1868 ± 224	2046 ± 214	0.0008
Creatinine (mg/dL)	1.68 ± 0.32	1.75 ± 0.40	0.0091
MTT _K	186.2 ± 40.5	137.6 ± 30.6	0.0025
Impairment of renal perfusion (mL/[min)	293 ± 44	156 ± 7	0.0010
T2 pronounce (milliseconds)	45.7 ± 1.2	60.1 ± 2.0	0.0040
T1 relaxation times (milliseconds)	1938 ± 53	1350 ± 27	0.0012
CNR efficiency (mm ² /s)	1.83 ± 0.05 × 10 ⁻³	1.39 ± 0.14 × 10 ⁻³	0.0085
Data are reported as mean ± SD. The <i>p</i> values were analyzed using independent sample <i>t</i> test.			

Discussion

The assessment of early CKD damage is of crucial importance in preventing CKD-induced diseases (13). In this study, we investigated the diagnostic efficacy of DTI-GBMRI in evaluating histopathology and renal efficiency in patients with in CKD patients. Functional parameters associated with renal impairment in kidney function were analyzed in DTI-GBMRI-diagnosed CKD patients with CKD. Findings in this study found DTI-GBMRI accurately imaged the pathological characteristics and depict renal efficiency in CKD patients. Thus, DTI-GBMRI may be a potential noninvasive method for measuring renal function for CKD patients.

CKD has been associated with increased visual impairment and cardiovascular disease (13). Inflammation and dysfunction of glomerular cells contributes to the cardiovascular disease burden associated with CKD, which is one of the most important risk factors for mortality and morbidity in CKD patients (14). Thus, it is very important to evaluate the degree of CKD and analyze abnormalities of kidney structure or function (15). MRI methods have become available for renal functional evaluation for patients with CKD, which can access renal function combined with high-resolution morphological evaluation of the kidneys and the entire urinary tract (16). In this study, we found that DTI-GBMRI presented higher efficacy in evaluating renal histopathology and renal efficiency, renal fibrosis and damage, noninvasive quantification of renal blood flow than DTI-MRI. Data reported that DTI-GBMRI clearly showed the diameters of lesions, good performance in measuring lumen depiction scores, intraluminal signal homogeneity, and CNR efficiency in CKD patients compared to DTI-MRI, suggesting DTI-GBMRI provided the possible origins of differences in estimates of CKD prevalence, and presented possible solutions for tackling the factors responsible for the reported variations in renal injury measurements.

Previously, MRI allows the assessment of markers of perfusion without the use of contrast media (17). A study highlighted the potential clinical benefits of early detection in patients predisposed to CKD by using MRI techniques, which provided structural and functional information in the kidney (7). Zhao *et al*/found that diffusion-weighted MRI can be used to assess renal fibrosis in CKD patients (18). Data in this study observed that DTI-GBMRI-diagnosed CDK patients had higher MTT_K , stronger impairment of renal perfusion and more pronounced increases in T2 and T1 relaxation times than DTI-MRI in CKD patients. However, there was no significant difference in evaluating kidney volumes between DTI-GBMRI and DTI-MRI groups. A previous study demonstrated that MRI could classify renal function, identify eGFR and functional renal parenchyma RBF in CKD patients (18, 19). Findings in the current study demonstrated that DTI-GBMRI-diagnosed CKD patients showed lower cortical RBF values and eGFR than those patients diagnosed by DTI-MRI.

MRI method has been used in diagnosing CKD for it is a noninvasive and accessible method (20–22). However, its operator dependency and low sensitivity reduce its utility in research. This study introduced gadolinium-based MRI to improve operator dependency and low sensitivity in diagnosing cortical RBFs eGFR, renal fibrosis, renal damage and eGFR in CKD patients. The strategies of this study compared the diagnostic efficacy between DTI-GBMRI and DTI-MRI, and outcomes found that DTI-GBMRI method showed the superior diagnostic accuracy, sensitivity and specificity compared to DTI-MRI in patients with CKD.

Conclusion

This study demonstrates the benefits of DTI-GBMRI in measuring renal histopathology and renal efficiency, renal fibrosis and damage, noninvasive quantification of renal blood flow in CDK patients. Outcomes find that DTI-GBMRI improves testing methodologies for more accurate assessment of cortical RBFs, GFR, pathological characteristics and depict renal efficiency than DTI-MRI, which further contributes to high sensitivity and specificity. These data suggest that DTI-GBMRI may be a reliable assessment of renal function combined with high-resolution morphological evaluation of the kidneys, as well as accurately identify stage CKD in certain clinical patients.

Abbreviations

CKD

chronic kidney disease

DTI-GBMRI

Diffusion tensor imaging findings generated by gadolinium-based MRI

RBF

renal blood flow

eGFR

estimated glomerular filtration rate

BP

blood pressure
ASCVD
atherosclerotic cardiovascular disease
US
ultrasonography
CEUS
contrast-enhanced ultrasound
CT
computed tomography
MRI
magnetic resonance imaging
CMR
cardiovascular magnetic resonance
GB
Gadolinium
MTT
mean transit time
ROC
receiver operating characteristic

Declarations

Ethics approval and consent to participate

This study was approved by the ethics committee of Hongqi Hospital Affiliated To Mudanjiang Medical University.

Consent for publication

All patients signed written informed consent and consent for publication.

Availability of data and material

The datasets used in this study are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

LH and GD collected data and made statistical analysis. SYB, HMC and TFQ contributed to data interpretation and manuscript preparation. LHY designed this study and wrote manuscript. All authors read and approved the final manuscript.

Acknowledgement

Not application

References

1. Hildegard Stancu S, Stanciu A, Lipan M, Capusa C. Renal anemia and hydration status in non-dialysis chronic kidney disease: Is there a link? *Journal of medicine life*. 2018;11:293–8.
2. Bhatia HS, Hsu JC, Kim RJ. Atrial fibrillation and chronic kidney disease: A review of options for therapeutic anticoagulation to reduce thromboembolism risk. *Clinical cardiology*. 2018;41:1395–402.
3. Bouya S, Balouchi A, Rafiemanesh H, Hesarakı M. Prevalence of Chronic Kidney Disease in Iranian General Population: A Meta-Analysis and Systematic Review. *Therapeutic apheresis and dialysis: official peer-reviewed journal of the International Society for Apheresis the Japanese Society for Apheresis the Japanese Society for Dialysis Therapy*. 2018;22:594–9.
4. Afsar B, Siriopol D, Aslan G, et al. The impact of exercise on physical function, cardiovascular outcomes and quality of life in chronic kidney disease patients: a systematic review. *Int Urol Nephrol*. 2018;50:885–904.
5. Ketteler M, Block GA, Evenepoel P, et al. Diagnosis, Evaluation, Prevention, and Treatment of Chronic Kidney Disease-Mineral and Bone Disorder: Synopsis of the Kidney Disease: Improving Global Outcomes 2017 Clinical Practice Guideline Update. *Ann Intern Med*. 2018;168:422–30.
6. Prasad GVR, Yan AT, Nash MM, et al. Determinants of Left Ventricular Characteristics Assessed by Cardiac Magnetic Resonance Imaging and Cardiovascular Biomarkers Related to Kidney Transplantation. *Canadian journal of kidney health disease*. 2018;5:2054358118809974.
7. Charlton JR, Beeman SC, Bennett KM. MRI-detectable nanoparticles: the potential role in the diagnosis of and therapy for chronic kidney disease. *Adv Chronic Kidney Dis*. 2013;20:479–87.
8. Bhave G, Lewis JB, Chang SS. Association of gadolinium based magnetic resonance imaging contrast agents and nephrogenic systemic fibrosis. *The Journal of urology* 180: 830–835; discussion 835, 2008.
9. Yantasee W, Fryxell GE, Porter GA, et al. Novel sorbents for removal of gadolinium-based contrast agents in sorbent dialysis and hemoperfusion: preventive approaches to nephrogenic systemic fibrosis. *Nanomedicine: nanotechnology biology medicine*. 2010;6:1–8.

10. Yu Y, Shumway KL, Matheson JS, Edwards ME, Kline TL, Lyons LA. Kidney and cystic volume imaging for disease presentation and progression in the cat autosomal dominant polycystic kidney disease large animal model. *BMC Nephrol.* 2019;20:259.
11. Yamamoto A, Zhang JL, Rusinek H, et al. Quantitative evaluation of acute renal transplant dysfunction with low-dose three-dimensional MR renography. *Radiology.* 2011;260:781–9.
12. Kim DW, Shim WH, Yoon SK, et al. Measurement of arterial transit time and renal blood flow using pseudocontinuous ASL MRI with multiple post-labeling delays: Feasibility, reproducibility, and variation. *Journal of magnetic resonance imaging: JMRI.* 2017;46:813–9.
13. Liu X, Liu K, Sun Q, et al. Efficacy and safety of febuxostat for treating hyperuricemia in patients with chronic kidney disease and in renal transplant recipients: A systematic review and meta-analysis. *Experimental therapeutic medicine.* 2018;16:1859–65.
14. Aomatsu A, Ookawara S, Ishibashi K, Morishita Y. Protective Effects of Diuretics Against the Development of Cardiovascular Disease in Patients with Chronic Kidney Disease: A Systematic Review. *Cardiovasc Hematol Agents Med Chem.* 2018;16:12–9.
15. Manski-Nankervis JE, Thuraisingam S, Lau P, et al. Screening and diagnosis of chronic kidney disease in people with type 2 diabetes attending Australian general practice. *Aust J Prim Health.* 2018;24:280–6.
16. Kirsch H, Mentzel HJ. [Renal functional diagnostics using magnetic resonance imaging]. *Radiologe.* 2018;58:914–24.
17. Odudu A, Francis ST, McIntyre CW. MRI for the assessment of organ perfusion in patients with chronic kidney disease. *Curr Opin Nephrol Hypertens.* 2012;21:647–54.
18. Zhao J, Wang ZJ, Liu M, et al. Assessment of renal fibrosis in chronic kidney disease using diffusion-weighted MRI. *Clinical radiology.* 2014;69:1117–22.
19. Li C, Liu H, Li X, Zhou L, Wang R, Zhang Y. Application of BOLD-MRI in the classification of renal function in chronic kidney disease. *Abdom Radiol (NY).* 2019;44:604–11.
20. Li R, Wang B, Owete O, et al. Landfill Leachate Treatment by Electrocoagulation and Fiber Filtration. *Water environment research: a research publication of the Water Environment Federation.* 2017;89:2015–20.
21. Albayrak E, Ozmen Z, Sahin S, Demir O, Erken E. Evaluation of cisterna chyli diameter with MRI in patients with chronic kidney disease. *Journal of magnetic resonance imaging: JMRI.* 2016;44:890–6.
22. Inoue T, Kozawa E, Ishikawa M, Okada H. [Assessment of chronic kidney disease using functional MRI]. *Nihon Jinzo Gakkai shi.* 2015;57:1225–32.

Tables

Table 1 Characteristic of CKD patients

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Number	94	92
Male/female	54/40	53/39
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Diastolic	82.6 ± 5.8	84.2 ± 6.5
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Smoking, n (%)	10 (10.6%)	10 (10.9%)
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Data are expressed as mean ± or n (%). The *P* values were calculated via independent sample *t* test for continuous variables and chi-square test for categorical variables. BMI, body mass index; CKD, chronic kidney disease.

Table 2 The pathological characteristics and depict renal efficiency diagnosed by DTI-GBMRI

	DTI-MRI	DTI-GBMRI	P value
Diameters of lesions (cm)	3.02 ± 0.32	3.28 ± 0.24	0.0045
Depiction scores	3.2 ± 0.2	4.8 ± 0.2	0.0032
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Venous outflow	2.2 ± 0.2	4.4 ± 0.2	0.0036
Intraluminal signal homogeneity	0.40 ± 0.05	0.24 ± 0.03	0.0057
CNR efficiency	2.6 ± 0.3	5.2 ± 0.3	0.0028

Data are reported as mean ± SD. The *p* values were analyzed using independent sample *t* test.

Table 3 Kidney volume and functional parameters estimates diagnosed by DTI-GBMRI

	DTI-MRI	DTI-GBMRI	P value
kidney volumes (ml)	1868 ± 224	2046 ± 214	0.0008
Creatinine (mg/dL)	1.68 ± 0.32	1.75 ± 0.40	0.0091
MTT _K	186.2 ± 40.5	137.6 ± 30.6	0.0025
Impairment of renal perfusion (mL/[min])	293 ± 44	156 ± 7	0.0010
T2 pronounce (milliseconds)	45.7 ± 1.2	60.1 ± 2.0	0.0040
T1 relaxation times (milliseconds)	1938 ± 53	1350 ± 27	0.0012
CNR efficiency (mm2/s)	1.83 ± 0.05 × 10 ⁻³	1.39 ± 0.14 × 10 ⁻³	0.0085

Data are reported as mean ± SD. The *p* values were analyzed using independent sample *t* test.

Table 4 Analysis of Cortical RBFs and eGFR in CDK patients

	DTI-MRI	DTI-GBMRI	P value
Serum creatinine (mg/dL)	1.68 ± 0.32	1.75 ± 0.40	0.0058
eGFR (mL/min/1.73 m ²)	36.4 ± 20.8	44.7 ± 16.5	0.0072
BRF (ml/min)	503.5 ± 32.4	315.8 ± 23.6	0.0020

Data are reported as mean ± SD. The *p* values were analyzed using independent sample *t* test.

Table 5 Diagnostic efficacy of DTI-GBMRI in CKD patients

	DTI-MRI	DTI-GBMRI	P value
Sensitivity (%)	86.8	98.5	0.0048
Specificity (%)	88.3	98.2	0.0070

Sensitivity and specificity differences between DTI-MRI and DTI-GBMRI were analyzed using Pearson nonparameter correlation analysis.

Figures

Figure 1

Flow diagram showing CKD patients in this study.

Figure 2

Receiver operating characteristic curve of DTI-GBMRI and DTI-MRI for the diagnosis of CKD patients.