COMPREHENSIVE ASSESSMENT OF KIDNEY ANATOMY AND PERFUSION WITH ARTERIAL SPIN LABELING MAGNETIC RESONANCE IMAGING

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Introduction

Renal perfusion is an important physiological parameter in health and disease. In normal physiology, renal blood flow is an important determinant of oxygen supply and glomerular filtration rate. In chronic kidney disease (CKD), renal microvascular dysfunction is one of a number of pathological mechanisms involved in the progression of disease, irrespective of the initiating insult. Despite this, in vivo measurement of renal perfusion remains a challenge for nephrologists in both clinical and research settings, as established methods are associated with a number of inherent drawbacks.

Renal arterial spin labelling magnetic resonance imaging (ASL MRI) is an emerging technique allowing measurement of perfusion using magnetised protons in blood as an endogenous tracer. We studied healthy volunteers (HV) and patients with chronic kidney disease (CKD) using ASL MRI at 3 Tesla.

Methods

Participants attended for 3T MRI (Siemens Verio), along with a clinical and biochemical assessment, including measurement of estimated glomerular filtration rate (eGFR). Historical biochemistry was derived from the electronic patient record.

Renal morphology was assessed on HASTE imaging. T1 maps were obtained using a MOLLI sequence, and T1 times were measured in cortex, medulla, and whole kidney, and corticomedullary differentiation (CMD) was calculated as the ratio of cortex to medulla T1 time.

ASL was performed using Flow sensitive alternating inversion recovery labelling and true fast imaging with steady state precession acquisition (FAIR True-FISP). Post processing was carried out using in house software to produce perfusion maps, and perfusion was measured in the cortex and whole kidney.

Results – Baseline Parameters

41 patients were recruited (24 HV and 17 CKD) with a mean age of 51.0 ± 13.3 years. The CKD group had higher body mass index (BMI) (29±3 vs 27±5 kg/m2; p<0.05), blood pressure (151/90±26/14 vs 132/83±15/8 mmHg; p<0.05) and lower CKD-EPI eGFR (39.9±25.2 vs 99.6±14.0 ml/min/1.73m2; p<0.001).

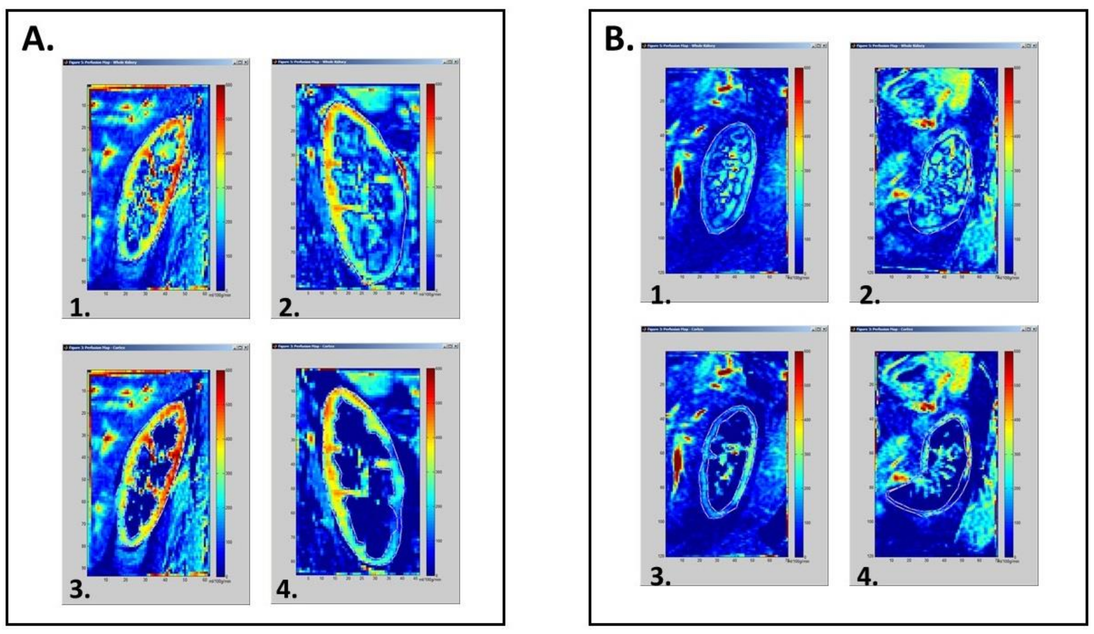
Parameter	Healthy volunteers	Chronic kidney disease	*p* value
Age (years)	47 ± 14	56 ± 10	< 0.05
Body mass index (kg/m^2)	26.5 ± 5.3	29.3 ± 3.4	0.06
Blood pressure (mmHg)	132/83 ± 15/8	151/90 ± 26/14	< 0.05
Mean arterial blood pressure (mmHg)	99 ± 9	110 ± 17	< 0.05
CKD-EPI eGFR (ml/min/1.73m2)	99.6 ± 14.0	39.9 ± 25.2	< 0.001
Kidney length (cm)	10.5 ± 0.8	9.7 ± 0.9	< 0.05
Kidney volume (cm3)	167.1 ± 35.0	160.1 ± 53.4	0.62
Cortical T1 time (ms)	1366 ± 122	1529 ± 77	< 0.001
Whole kidney T1 time (ms)	1472 ± 91	1550 ± 81	< 0.01
Corticomedullary differentiation	0.84 ± 0.07	0.94 ± 0.07	< 0.001
Mean cortical perfusion (ml/min/100g)	279 ± 69	136 ± 37	< 0.001
Mean whole kidney perfusion (ml/min/100g)	221 ± 38	146 ± 24	< 0.001
Mean kidney perfusion (ml/min)	366 ± 79	223 ± 75	< 0.001
Total renal perfusion (ml/min)	731 ± 159	446 ± 150	< 0.001

Results – Kidney anatomy

Kidney anatomy was assessed, with significantly shorter length (9.7±0.9 vs 10.5±0.8 cm; p<0.05), and numerically smaller volume (160.1±53.4 vs 167.1±35.0 cm3; p=NS) in the CKD group compared to healthy volunteers. Furthermore, the CKD group had higher cortical T1 (1529±77 vs 1365±122 ms; p<0.01) and whole kidney T1 (1550±81 vs 1472±91 ms; p<0.05), and reduced CMD (0.94 vs 0.84; p<0.01)..

Results - Perfusion

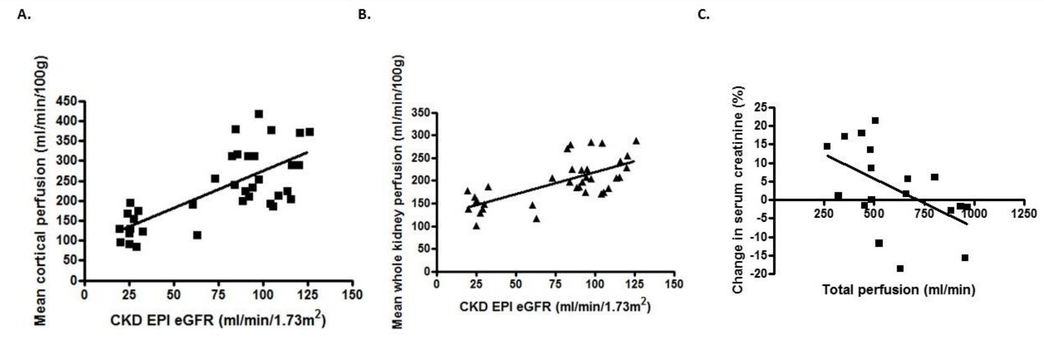
Perfusion was demonstrably lower in the CKD group, both measured in the cortex (136.2±36.8 vs 279.2±69.0 ml/min/100g; p<0.01) and the whole kidney (146.0±24.4 vs 221.0±37.8 ml/min/100g; p<0.01). Total renal perfusion was also lower in the CKD group (446.5±150.0 vs 731.1±158.5 ml/min; p<0.01).



ASL MRI perfusion maps from a healthy volunteer (A) and patient with chronic kidney disease stage 3/4 (B) with an eGFR of 30 ml/min/1.73m2. Both whole kidney (1 & 2) and cortical (3 & 4) perfusion are demonstrated. Cortical thinning, reduced corticomedullary differentiation, and reduced global perfusion can be seen in CKD

Results – Associations with clinical parameters

Correlation was observed between eGFR and cortical perfusion (r = 0.73, p<0.01) (A), and whole kidney perfusion (r = 0.69, p <0.01) (B). There was also a negative association between the change in serum creatinine over the preceding year, and both cortical (r = -0.38, p<0.05) and total renal perfusion (r = -0.48, p<0.05) (C).



Conclusion

ASL MRI is able to robustly demonstrate the differences in renal structure and function between patients with CKD and healthy volunteers. Cortical and total perfusion may represent a factor associated with progression of renal impairment. Further research into the utility of ASL MRI in the assessment of chronic kidney disease is required.

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