551-02-016 / 551-02-016 ISMRM ABSTRACT

Evaluation of Renal Blood Flow using PCASL in Chronic Kidney Disease patients and healthy controls: preliminary results from

Primary: Contrast Mechanisms - Arterial Spin Labelling 〉 **Secondary:** Body - Kidney 〉 **PowerPitch Oral** · 2 min + **Digital Poster** · 60 min | MRI of Renal Function · 2:10 PM–2:12 PM · Session: 1:40–3:16 PM · Power Pitch Theatre 1 〉 **Keywords:** RENAL BLOOD FLOW PCASL CHRONIC KIDNEY DISEASE RENAL PERFUSION ARTERIAL SPIN LABELING (ASL)

Rebeca Echeverria-Chasco [1,2], **Leyre Garcia-Ruiz**[1], **Malene Aastrup**[3], **Verónica Aramendía-Vidaurreta**[1], **Michela Bozzetto**[4], **Paolo Brambilla**[5], **Esben S Hansen**[6], **Jose Maria Mora-Gutierrez**[7], **Siria Pasini**[8], **Anish Raj**[9], **Steffen Ringgaard**[6], **Anika Strittmatter**[9], **Manuel Taso**[10], **Ioana Urdea**[11], **Tau Vendelboe**[6], **Marta Vidorreta**[12], **GIULIA VILLA**[4], **Niels H Buus**[13], **Nuria Garcia-Fernandez**[7], **Matias Trillini**[4], **David C Alsop**[14], **Susan Francis**[15], **Christoffer Laustsen**[6], **Frank G Zoellner**[16], **Anna Caroli**[4], **Maria Fernandez-Seara**[1,2]

[1]Radiology, Clinica Universidad de Navarra, Pamplona, Spain
[2]Navarra Institute for Health Research (IdiSNa), Pamplona, Spain
[3]Aarhus University, Aarhus, Denmark
[4]Istituto di Ricerche Farmacologiche Mario Negri IRCCS, Ranica (BG), Italy
[5]ASST Papa Giovanni XXIII, Bergamo, Italy
[6]MR Research Centre, Aarhus University, Aarhus, Denmark
[7]Nephrology, Clinica Universidad de Navarra, Pamplona, Spain
[8]Bioengineering, Istituto di Ricerche Farmacologiche Mario Negri IRCCS, Ranica (BG), Italy
[9]Heidelberg University, Heidelberg, Germany
[10]Siemens Medical Solutions USA, Inc., Malvern, United States of America
[11]Siemens, Brasov, Romania
[12]Siemens Healthcare, Madrid, Spain
[13]Aarhus University Hospital, Aarhus N, Denmark
[14]Beth Israel Deaconess Medical Center, Boston, United States of America
[15]Sir Peter Mansfield Imaging Center, University of Nottingham, Nottingham, United Kingdom
[16]Computer Assisted Clinical Medicine, Medical Faculty Mannheim, Heidelberg University, Mannheim, Germany

Presenting Author: *Rebeca Echeverria-Chasco (recheverriac@unav.es)*

Impact

Harmonized PCASL sequences show promise for renal blood flow measurements in CKD patients and controls in a multi-center and multi-vendor study. RBF is significantly reduced in patients with CKD stage 3 compared to CKD Stage 2 patients and controls

Synopsis

Motivation: Chronic kidney disease (CKD) is associated with reduced renal blood flow (RBF). ASL can estimate RBF, however ASL data acquired with harmonized sequences are limited.

Goals: Evaluate RBF differences in CKD patients and healthy volunteers (HV) using harmonized PCASL at 3T systems of different vendors.

Approach: HV and CKD (Stage 2 and 3) patients were scanned at two centers using harmonized PCASL sequences across vendors. RBF maps were computed and used in a general linear model to assess differences among groups.

Results: RBF values: HV (n=40): 229±50ml/min/100g, CKD2(n=20): 235±41ml/min/100g, CKD3(n=20): 185±53 ml/min/100g. RBF was significantly reduced in CKD3 compared to CKD2 and HV.

Introduction

Chronic kidney disease (CKD) affects over 800 million people globally, with higher prevalence in older adults, women, and individuals with diabetes or hypertension[1]. It is a leading cause of death and one of the few silent diseases with rising mortality[2].

As CKD progresses toward end-stage renal disease, altered renal hemodynamics result in diminished perfusion, leading to reduced renal blood flow (RBF)[3].

Arterial Spin Labeling (ASL) can provide contrast-free assessment of kidney perfusion[4]. Despite promising single-center and single-vendor studies, methodological variability limits its clinical adoption.

This multicenter and multivendor study, conducted as part of the European RESPECT project, aims to characterize and stage CKD using harmonized pseudo-continuous arterial spin labeling (PCASL) sequences in healthy volunteers (HV) and CKD patients.

Methods

The study was approved by local Ethics Research Committees. Written informed consent was obtained from all subjects.

Study Design:
Two centers participated in this study, providing MRI data from 3T scanners of two different vendors. Twenty HV and 20 CKD patients (stage 2 and 3) were recruited at each center by participating nephrologists.

HVs were scanned twice on the same day (exams 1, 2), followed by a third scan after 7–14 days (exam 3), while CKD patients were scanned twice within 7–14 days. Blood and urine samples were collected on the first visit. Estimated glomerular filtration rate (eGFR) was calculated using the 2021 CKD-EPI equation based on creatinine[5].

MRI Protocol:
ASL sequences employed optimized PCASL configurations. For vendor 1, a research PCASL sequence with FSE readout was used[6], while for vendor 2, a research PCASL sequence with SE-EPI readout. [7] Sequences were harmonized in terms of labeling parameters, post-labeling delay, labeling duration, the use

of background-suppression pulses and 2D readouts, following PARENCHIMA recommendations[4]. Sequence details are in Figure 1.

ASL Postprocessing:
CKD and HV data from exam 1 were analyzed. ASL images were motion-corrected using non-rigid transformation algorithms. RBF was quantified using the single-compartment model.[4] The renal cortex was manually segmented in the central slice of the M0 image or T1 maps, avoiding cysts and artifacts.

Statistical Analysis:
Statistical analysis was performed using R. Normally distributed data are expressed as mean±standard deviation, and non-normally distributed data as median (interquartile range). Age, serum creatinine, eGFR, and urine albumin-to-creatinine ratio (UACR) were compared across groups using one-way analysis of variance (ANOVA) with a between-subject factor: group (3 levels = HV, CKD2, CKD3), while sex differences using Fisher's exact test.
To assess the ability of cortical RBF to distinguish between HV, CKD2, and CKD3 patients, a general linear model (GLM) was employed with group (3 levels) as the independent variable, and age, sex, and center as potential confounding factors[8]. GLM assumptions were checked.
In all analyses, a p-value < 0.05 was considered statistically significant, with correction for multiple comparisons where applicable.

Results and discussion

Data from 40 HV, 19 CKD2, and 21 CKD3 patients were analyzed. Demographic and clinical characteristics are summarized in Figure 2. All parameters were normally distributed except for UACR. No significant differences were found in age or sex among groups, however age was slightly elevated in CKD3 group. Significant differences among groups were observed in creatinine and eGFR. UACR was significantly lower in healthy controls compared to CKD2 and CKD3 patients.

Figure 3 shows RBF maps from representative subjects. Boxplots of eGFR and RBF measurements are shown in Figure 4. RBF values (Figure 2) for all groups were similar across both centers and consistent with the literature[7]. Group mean RBF values: HV=229±50 ml/min/100g, CKD2=235±41 ml/min/100g, CKD3=185±53 ml/min/100g.

GLM analysis revealed a significant main effect of group (p-value=0.0092), after adjusting for confounding variables. Age was a significant co-variate (p-value=0.0002), while sex (p-value=0.1583) and center (p-value=0.0664) were not. Post-hoc comparisons showed that RBF in heahty volunteers was significantly higher than in CKD3 patients (p=0.0278) and RBF in CKD2 was significantly higher than in CKD3 (p=0.0412). No significant difference in RBF between controls and CKD2 patients was found (p-value=0.79).

Limitations should be noted. Motion correction, which is critical for accurate RBF estimation, was not consistently successful during all the free-breathing acquisitions. Cortical segmentation were drawn manually, which may have introduced a bias in the measurements. Sample size was relatively small; however, recruitment and data collection are still in progress. Future work will include automatic/semi-automatic approaches in anatomical images co-registered with ASL data. Additionally, the data of all the centers and exams will be analyzed.

Conclusion

In conclusion, RBF measurements with harmonized sequences among centers showed similar RBF values across vendors. RBF at Stage 3 of CKD is significantly reduced compared to healthy controls and Stage 2 of CKD.

Acknowledgements

This study was supported by the Italian Ministry of Health, Gobierno de Navarra, German Federal Ministry of Research, Technology and Space (BMFTR, grant number 01KU2102), and Innovation Fund Denmark (IFD), under the frame of ERA PerMed (RESPECT project, n. ERAPerMed-2020-326) and EPPerMed (EPPERMED2024-168).

References

1. Kovesdy CP. Epidemiology of chronic kidney disease: an update 2022. Kidney Int Suppl (2011). 2022 Apr;12(1):7-11. doi: 10.1016/j.kisu.2021.11.003. Epub 2022 Mar 18. PMID: 35529086; PMCID: PMC9073222. [pmid]

2. Charles J. Ferro, Christoph Wanner, Valerie Luyckx, Monica Fontana, Daniel Gallego, Raymond Vanholder, Roser Torra, Alberto Ortiz, A call for urgent action on chronic kidney disease across Europe, The Lancet Regional Health - Europe, Volume 54, 2025, 101347, ISSN 2666-7762, https://doi.org/10.1016/j.lanepe.2025.101347

3. Li, L. P., Tan, H., Thacker, J. M., Li, ... & Prasad, P. V. (2017). Evaluation of renal blood flow in chronic kidney disease using arterial spin labeling perfusion magnetic resonance imaging. Kidney international reports, 2(1), 36-43.

4. Nery, F., Buchanan, C. E., Harteveld, A. A., Odudu, A., Nery, F., Buchanan, C. E., Harteveld, A. A., Odudu, A., Bane, O., Cox, E. F., ... & Fernández-Seara, M. A. (2020). Consensus-based technical recommendations for clinical translation of renal ASL MRI. Magnetic Resonance Materials in Physics, Biology and Medicine, 33(1), 141-161.

5. Inker, L. A., Eneanya, N. D., Coresh, J., Tighiouart, H., Wang, D., Sang, Y., ... & Levey, A. S. (2021). New creatinine-and cystatin C–based equations to estimate GFR without race. New England Journal of Medicine, 385(19), 1737-1749.

6. Taso, M., Guidon, A., & Alsop, D. C. (2019). Influence of background suppression and retrospective realignment on free-breathing renal perfusion measurement using pseudo-continuous ASL. Magnetic resonance in medicine, 81(4), 2439-2449.

7. Echeverria-Chasco, R., Vidorreta, M., Aramendía-Vidaurreta, V., Cano, D., Escalada, J., Garcia-Fernandez, N., ... & Fernández-Seara, M. A. (2021). Optimization of pseudo-continuous arterial spin labeling for renal perfusion imaging. Magnetic Resonance in Medicine, 85(3), 1507-1521.

8. Weinstein, Jessica R., and Sharon Anderson. "The aging kidney: physiological changes." Advances in chronic kidney disease 17.4 (2010): 302-307.

Figures and Tables

	Vendor 1			Vendor 2			
READOUT PARAMETERS							
SE-EPI				**SSFSE**			
TR/TE (ms)	5000/22	**Number of slices**	5	**TR/TE (ms)**	6000/40	**Number of slices**	1
Flip angle	90	**Slice gap (mm)**	2.5	**Flip angle**	90	**Slice gap (mm)**	--
Partial Fourier	0.75	**Phase oversampling**	25%	**Partial Fourier**	0.54	**Phase oversampling**	--
GRAPPA	2	**Bandwith (Hz/pixel)**	2056	**GRAPPA**	None	**Bandwith (Hz/pixel)**	1627
FOV (mm2)	384x384	**Fat suppression**	FAT SAT	**FOV (mm2)**	340x340	**Fat suppression**	NONE
Acquisition matrix	128x128	**Slice orientation**	Coronal-oblique	**Acquisition matrix**	128x128	**Slice orientation**	Coronal
Slice thickness (mm)	5	**Slice Acq. Order**	Central Slice First	**Slice thickness (mm)**	5	**Slice Acq. Order**	
Voxel Size (mm)	3x3x5	**Breathing strategy**	respiratory trigger	**Voxel Size (mm)**	2.7x2.7x5	**Breathing strategy**	free breathing
PCASL LABELING PARAMETERS							
Labeling duration	1500	**B1 (uT)**	1.6	**Labeling duration**	1500	**B1 (uT)**	1.4
Post-labeling delay	1500	**BS Slice Selective**	FOCI	**Post-labeling delay**	1525	**BS Slice Selective**	FOCI
Average Gradient	0.4 mT/m	**BS No-Selective**	Tanh	**Average Gradient**	0.5 mT/m	**BS No-Selective**	HS
Ratio	7	**Number of images**	25 label, 25 control, 1 M0	**Ratio**	7	**Number of images**	14 label, 14 control, 1 M0

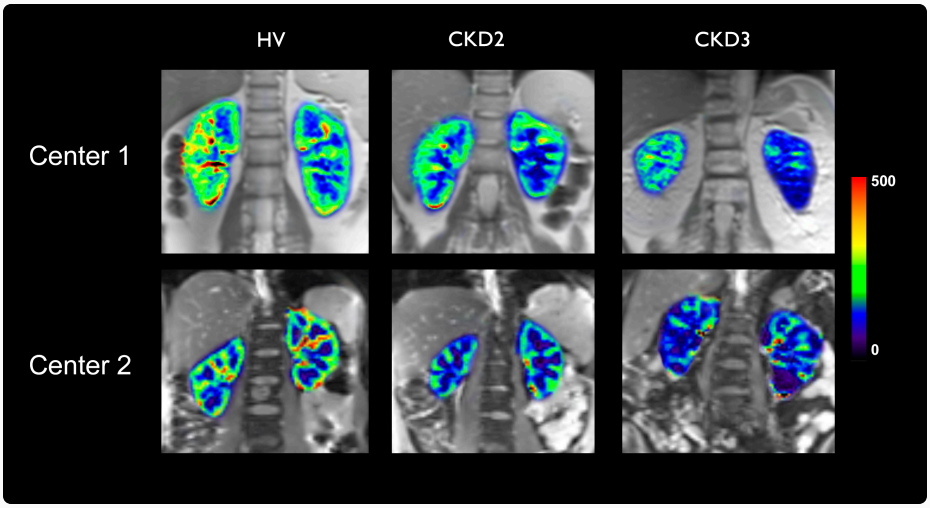
Scan for high-resolution version

Figure 1: Sequence parameters

		HEALTHY VOLUNTEERS (HV)		CKD STAGE 2 (CKD2)		CKD STAGE 3 (CKD3)	
n		40		19		21	
	1	20		9		11	
	2	20		10		10	
Age (years)		59 ± 14		58 ± 13		65 ± 14	
	1	58 ± 14		53 ± 12		60 ± 16	
	2	60 ± 13		62 ± 12		69 ± 10	
Sex (Number, % Female)		19 , 48%		10 , 53%		7 , 33%	
	1	10 , 50%		5 , 56%		4 , 36%	
	2	9 , 45%		5 , 50%		3 , 30%	
Creatinine (mg/dL)		**0.83 ± 0.15**		**0.99 ± 0.16**	*	**1.53 ± 0.30**	*#
	1	0.84 ± 0.13		1.02 ± 0.16		1.52 ± 0.31	
	2	0.83 ± 0.17		0.96 ± 0.16		1.52 ± 0.28	
eGFR (2021 CKD-EPI Creatinine) (ml/min/1.73m^2)		**90.17 ± 13.91**		**72.21 ± 9.34**	*	**45.0 ± 11.38**	*#
	1	87.70 ± 12.03		71.56 ± 6.70		45.9 ± 11.24	
	2	92.63 ± 14.85		72.80 ± 11.16		44.3 ± 11.10	
Urine albumin to creatinine ratio (UACR) (mg/g)		**4.80 (3.05 , 7.9)**		**207.00 (13.57, 532.08)**	*	**312.78 (46 , 732.1)**	*
	1	3.46 (3.02 , 5.28)		171.88 (81.22 , 475.36)		312.78 (98.66 , 463.35)	
	2	5.55 (3.7 , 8.68)		256.5 (9.05 , 553.85)		238.85 (38.02 , 888.32)	
Renal Blood Flow, RBF (ml/min/100g) *		**228.25 ± 49.83**		**235.15 ± 41.23**		**184.85 ± 52.78**	*#
	1	210.66 ± 36.64		230.05 ± 34.79		199.34 ± 44.70	
	2	245.84 ± 55.75		239.73 ± 45.79		168.79 ± 54.61	

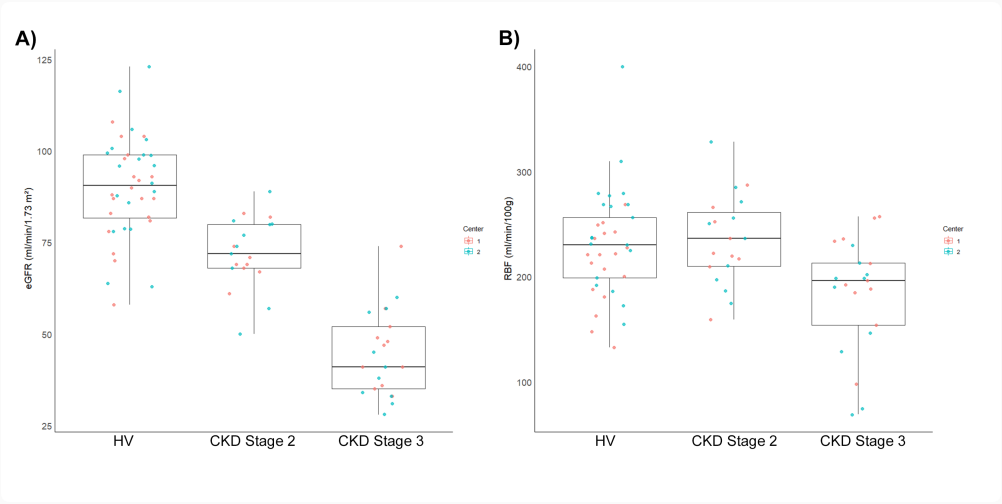
Scan for high-resolution version

Figure 2: Table showing demographic, clinical data and RBF values for all groups and centers. Group mean values are shown in grey, while data from Center 1 and 2 are separately averaged. Values are expressed as mean ± standard deviation, or median (IQR1, IQR3). Significant differences are shown in bold; * indicates p-value <0.05 for CKD Stage 2 or 3 versus healthy volunteers, and # indicates p-value < 0.05 for CKD Stage 3 versus CKD Stage 2.



Scan for high-resolution version

Figure 3: RBF maps of a representative subject of each group (HV, CKD2 and CKD3) and center (1,2).



Scan for high-resolution version

Figure 4: Group mean boxplots for eGFR (panel A) and RBF (panel B) for each group and center.