Contrast-enhanced CT imaging in patients with chronic kidney disease

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Introduction

Microvascular rarefaction is a common finding in kidneys of patients and experimental animals with CKD and fibrosis and was well characterized with immunohistochemical methods. Our previous animal study suggested that contrast enhanced micro-CT in animal models of progressive kidney diseases closely reflects peritubular capillary (PTC) rarefaction by quantification of relative renal blood volume (rBV).

(Ehling et al., J Am Soc Nephrol, 2014; Kramann et al., J Am Soc Nephrol, 2014; Advani et al., PLoS One, 2011; Boor et al., Nat Rev Nephrol, 2010; Basile et al., Am J Physiol Renal Physiol, 2001)

AIM: Analyse contrast enhanced CT imaging for evaluation of peritubular capillary rarefaction in patients with CKD.

Summary & Conclusion

Relative renal blood volume (rBV) in patients with contrast enhanced CT showed:

- Reduced cortical rBV in CKD patients
- Close correlation with histological capillary rarefaction & increased fibrosis
- Close correlation with GFR in longitudinal study

Morphometric analyses in patient CT and virtual CT angiography:

- Show reduced preglomerular artery diameters and reduced number branching points in CKD

CT angiography imaging could be a measure of microvascular rarefaction in CKD patients and of vascular morphometry in virtual autopsy.
Results in CKD patients mirror closely those in animal models, suggesting high relevance of the animal models for studying vascular changes in CKD.

Methods & Results

Study setup

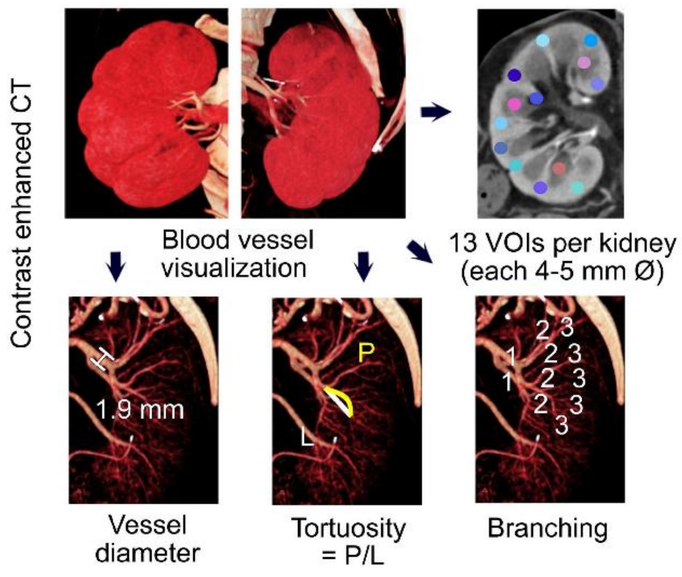
Patient cohort: The arterial phase of CT angiography was evaluated. Renal perfusion was determined by quantification of renal rBV determined by measuring the CT signal intensity in HU separately for cortex and medulla and normalization to the signal of aorta. 3D morphometric studies of intrarenal arteries were performed (Ehling et al., JASN 2016). Next, rBV was measured longitudinally in patients with consecutive CT angiographies including the kidneys.

Virtual autopsy cohort: Full-body post-mortem CT angiography was performed as previously described (Westphal et al., Human Pathology, 2014) by filling the arterial vascular system with contrast agent. 3D morphometric studies of intrarenal arteries were performed.

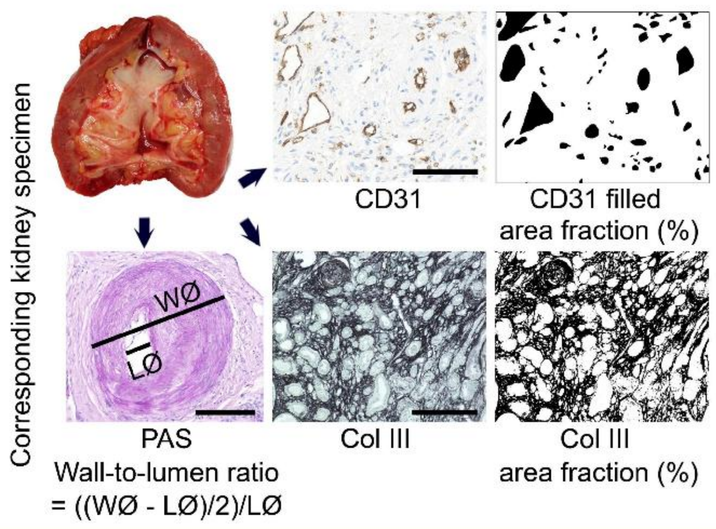
Histopathological analyses: Corresponding patient's kidney specimens were obtained from tumor nephrectomies or at autopsy. CD31 filled area fraction and collagen type III positive area fraction were quantified using image analysis software. Wall-to-lumen ratio was measured on PAS stained sections.

Patient cohort		Virtual autopsy cohort	
Normal	CKD	Normal	CKD
N = 5	N = 6	N = 3	N = 3

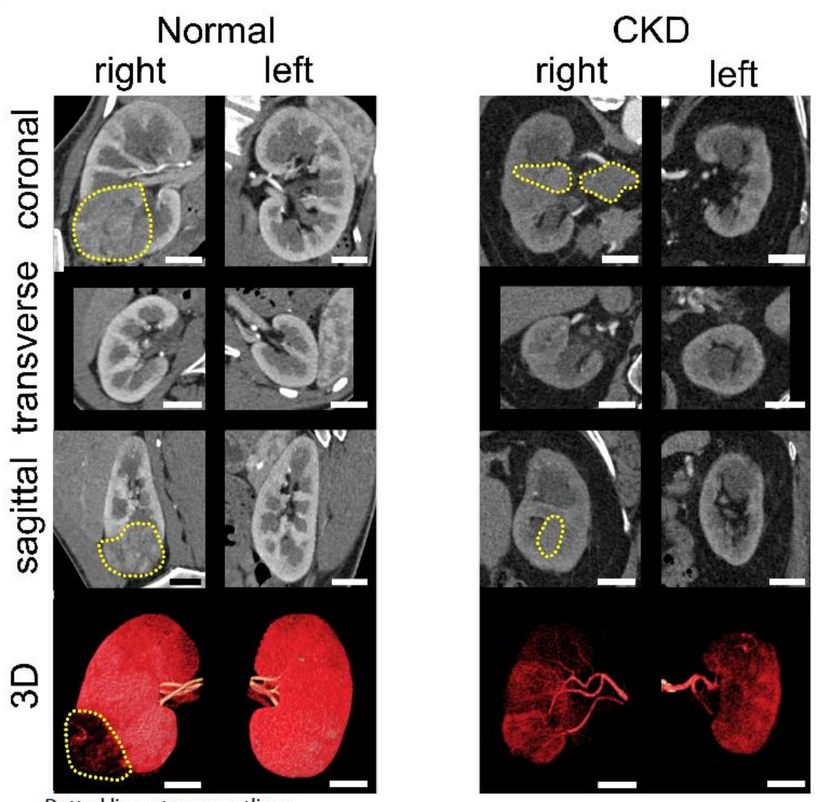
I. Anatomical imaging of renal vasculature



II. Immunohistochemistry and quantification

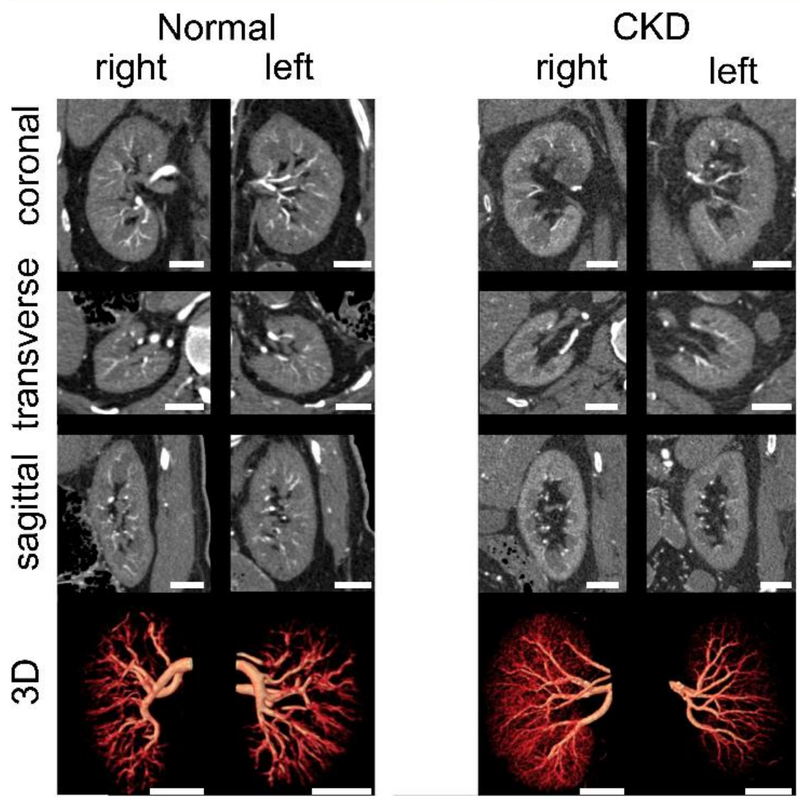


Patient CT

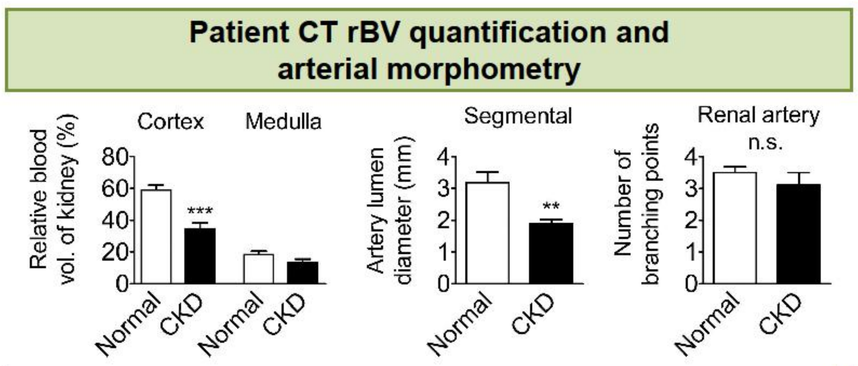


Dotted lines: tumor outlines

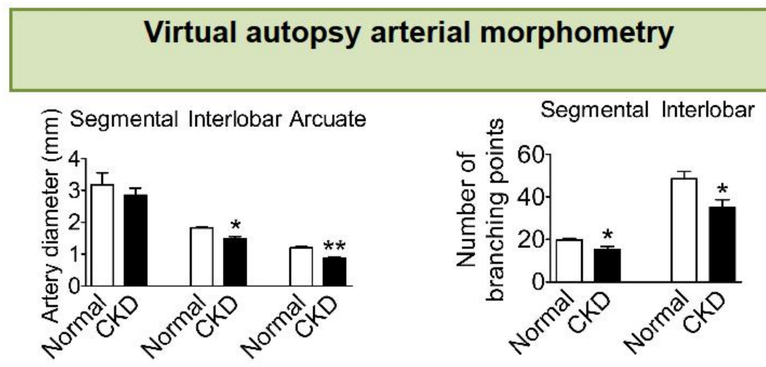
Virtual autopsy CT



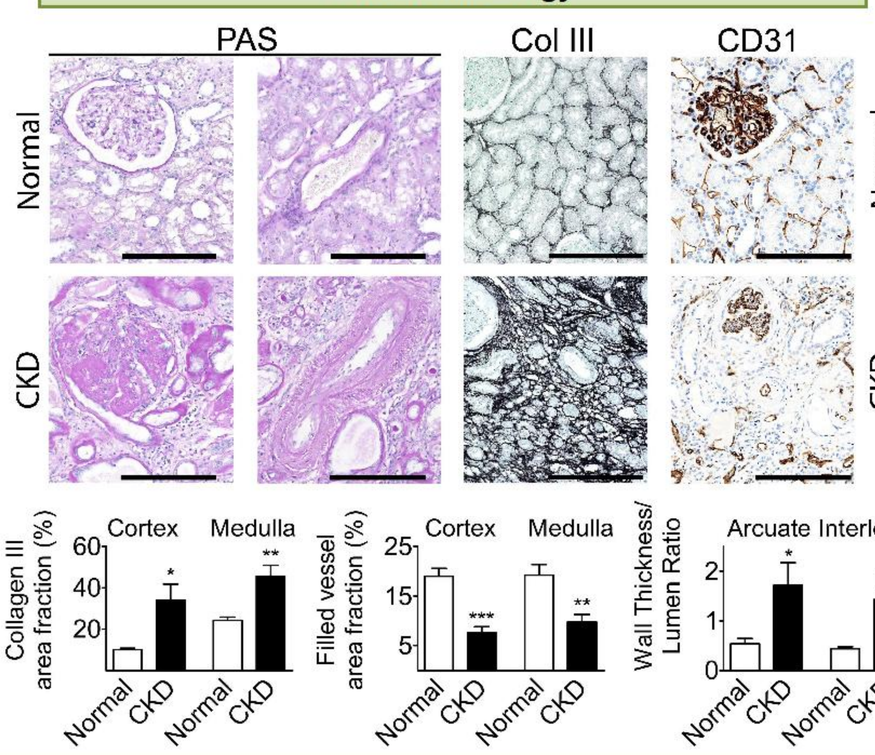
Patient CT rBV quantification and arterial morphometry



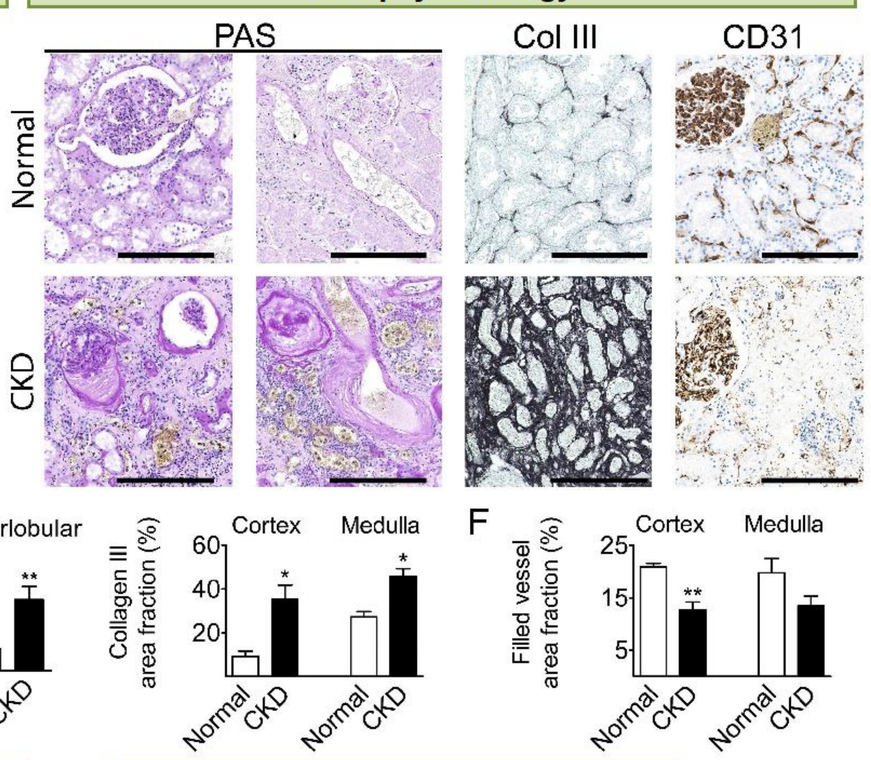
Virtual autopsy arterial morphometry



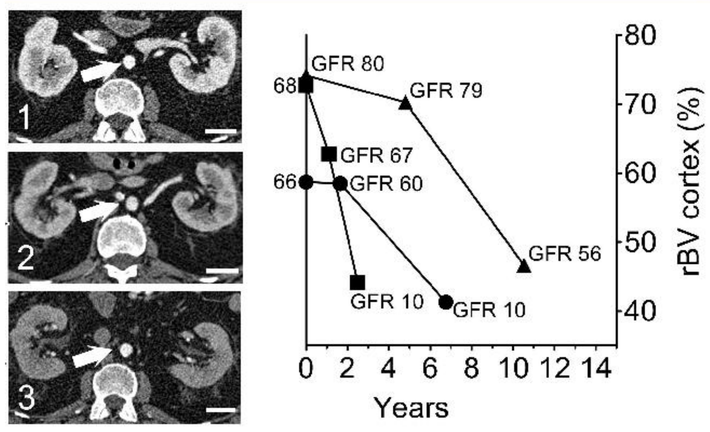
Patient histology

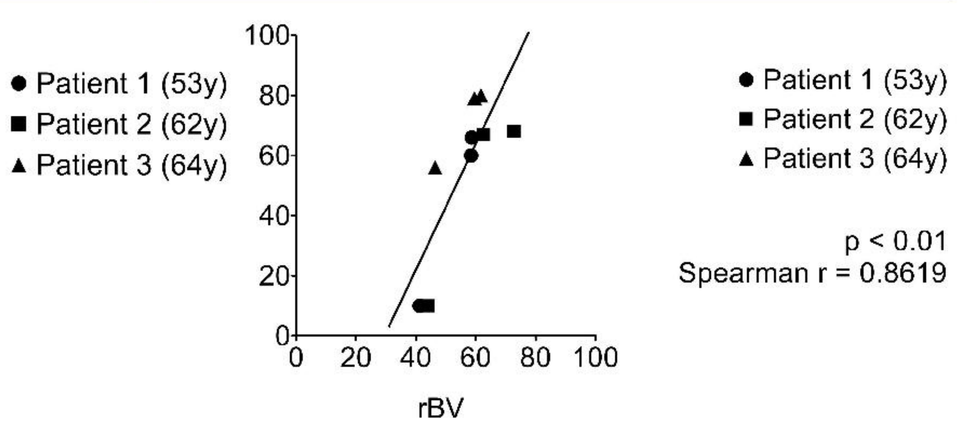


Autopsy histology



Longitudinal rBV quantification





$p < 0.01$
Spearman r = 0.8619

Abbreviations

CKD – chronic kidney disease
AKI – acute kidney injury
PTC – peritubular capillary rarefaction
CT – computed tomography
CE-CT – contrast enhanced computed tomography
Col III – Collagen type III
rBV – relative blood volume
HU – Hounsfield Units
VOI – volume of interest

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