

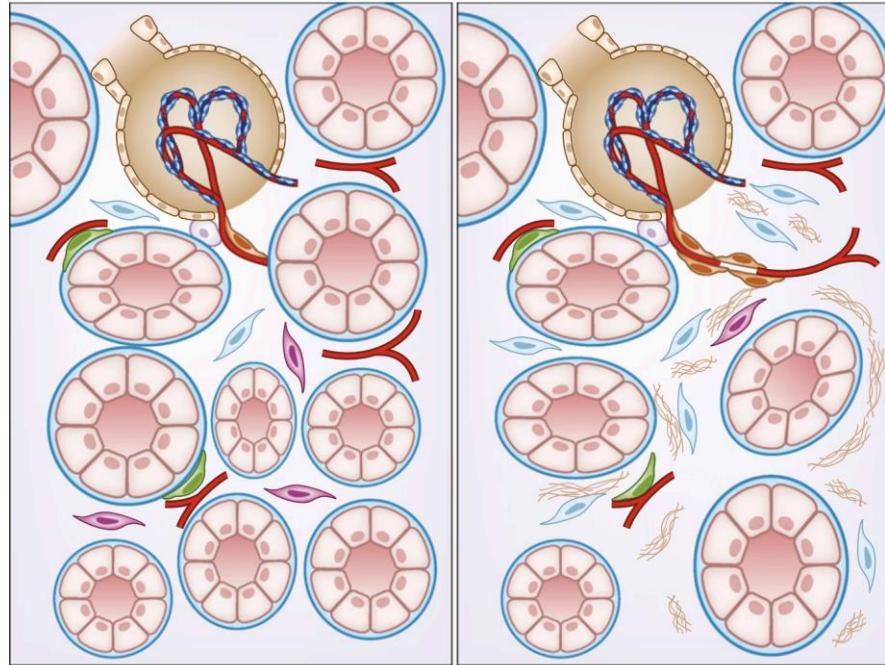
# **An overview of the application of T1 and T2 mapping in renal imaging**

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Leiden University Medical Center  
The Netherlands**

# Outline

- What is renal T1 and T2 mapping?
- Overview of renal T1 mapping studies
- Overview of renal T2 mapping studies
- Remaining challenges

# Pathophysiology of tubulointerstitial fibrosis

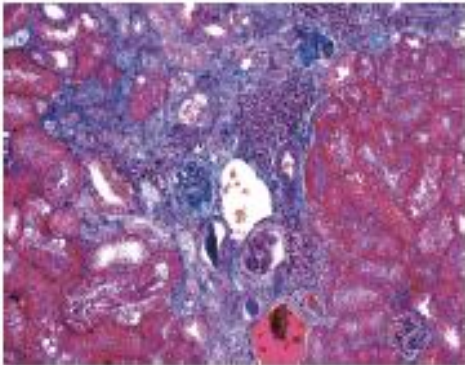


- Fibroblast
- Microvessel
- fibrotic ECM
- Perivascular cell
- Epo-producing fibroblast
- Renin-producing perivascular cell
- Renin-producing juxtaglomerular cell

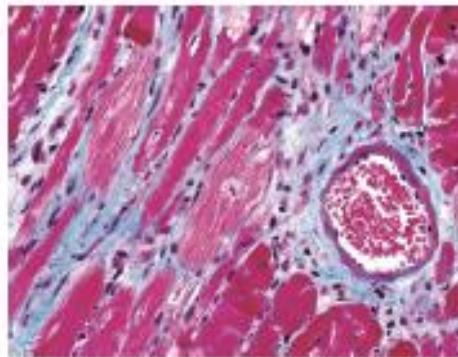
# Tissue characterization with MRI

Pathologic changes in tissue composition affect the behavior of nuclei undergoing resonance

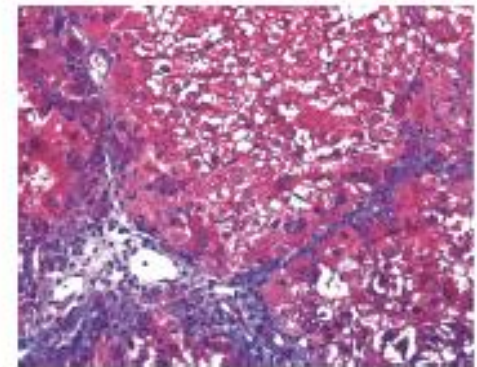
**Kidney**



**Heart**



**Liver**



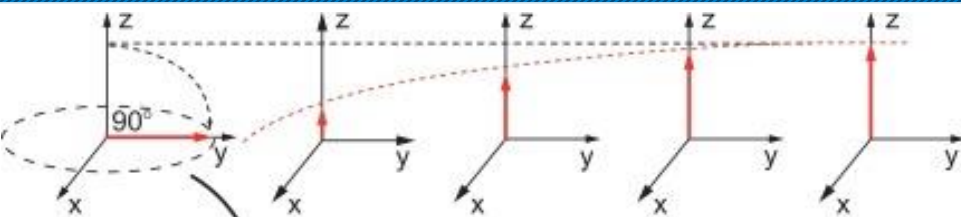
**T1 values**

at 3T:  $\uparrow 1403 \pm 76$  |  $1604 \pm 98$  ms

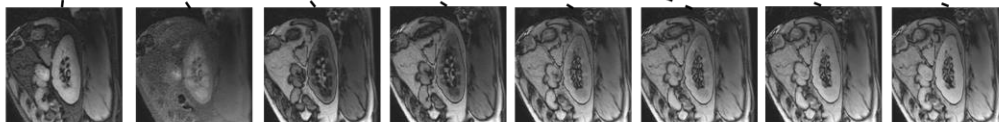
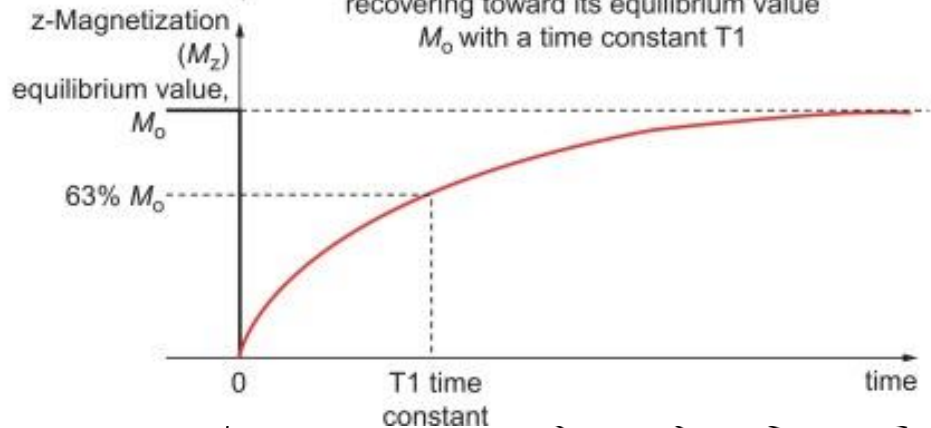
$\uparrow 1442 \pm 84$  ms

$\uparrow 895 \pm 105$  ms

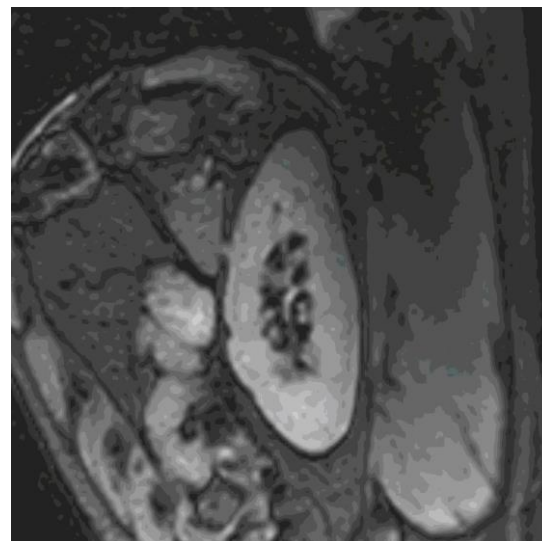
# T1 mapping



$M_z$  follows an exponential recovery, recovering toward its equilibrium value  $M_0$  with a time constant  $T_1$

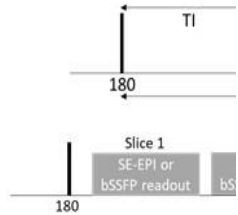


123 ms    350 ms    1723 ms    1950 ms    3323 ms    3550 ms    4923 ms    6523 ms

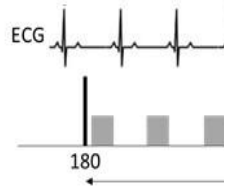


# Renal T1 mapping acquisition schemes

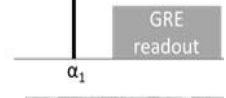
A Classic IR Schem



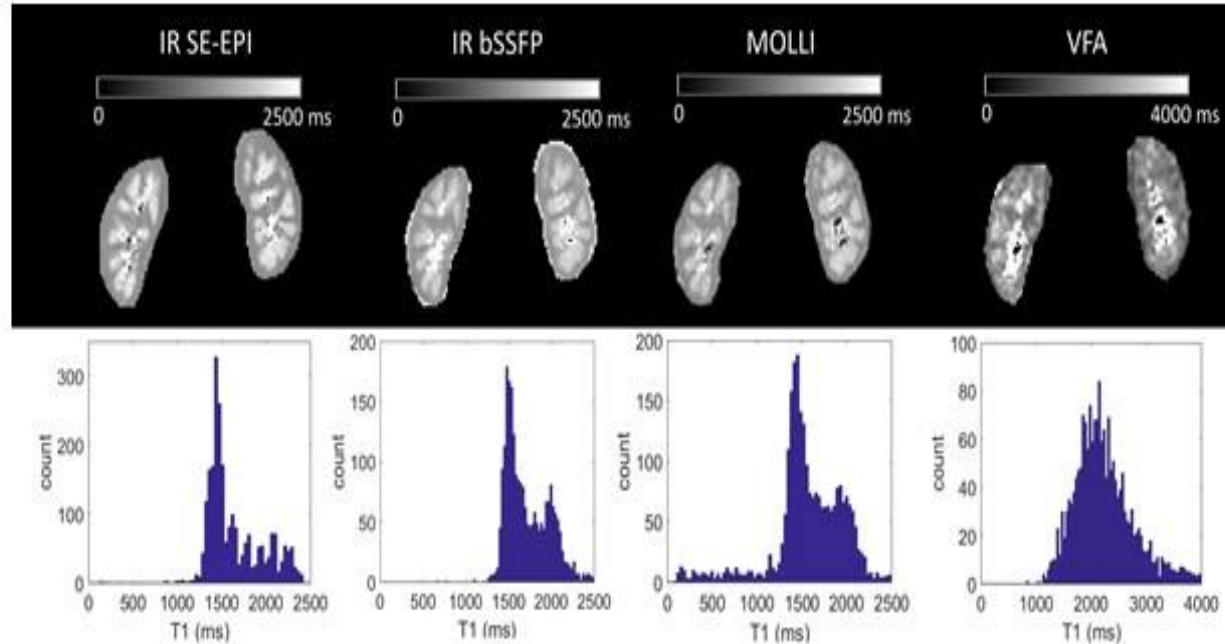
B MOLLI



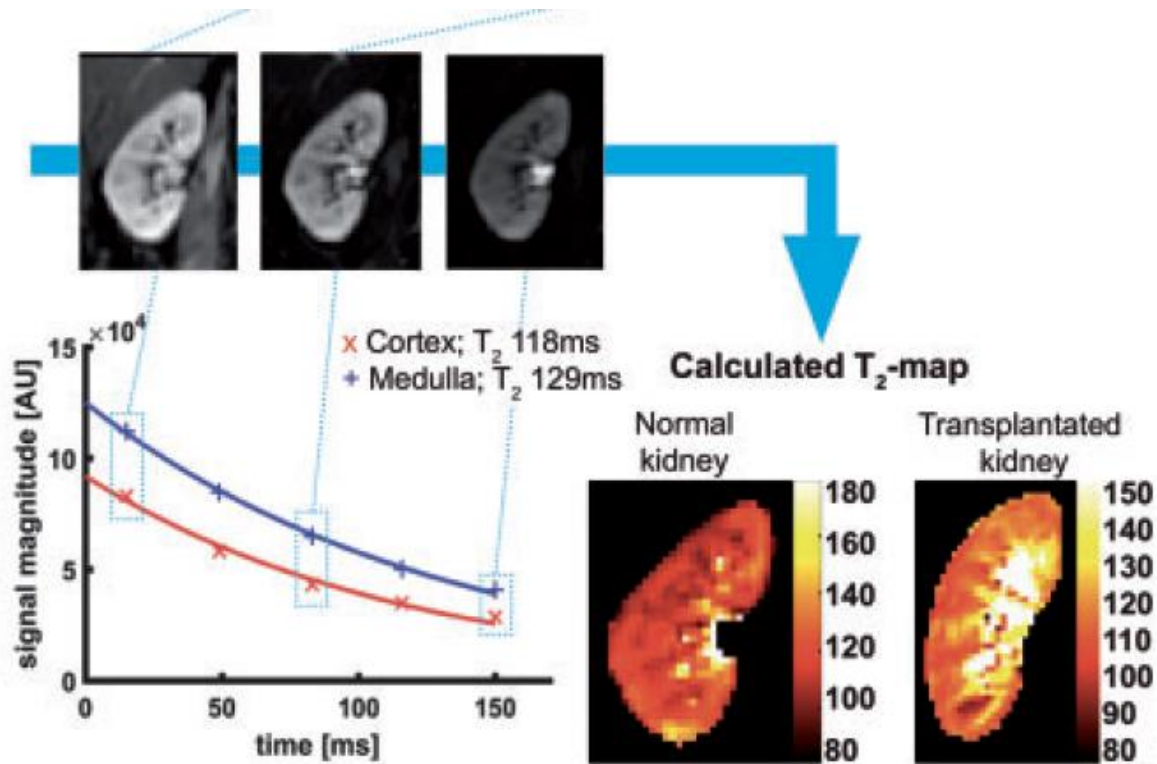
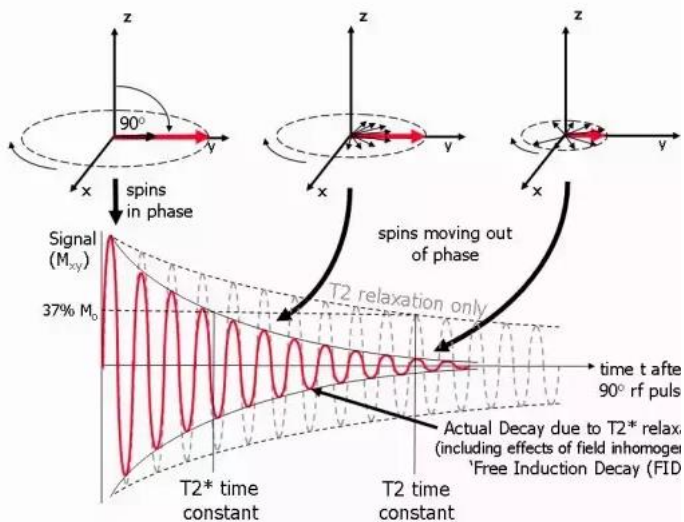
C VFA



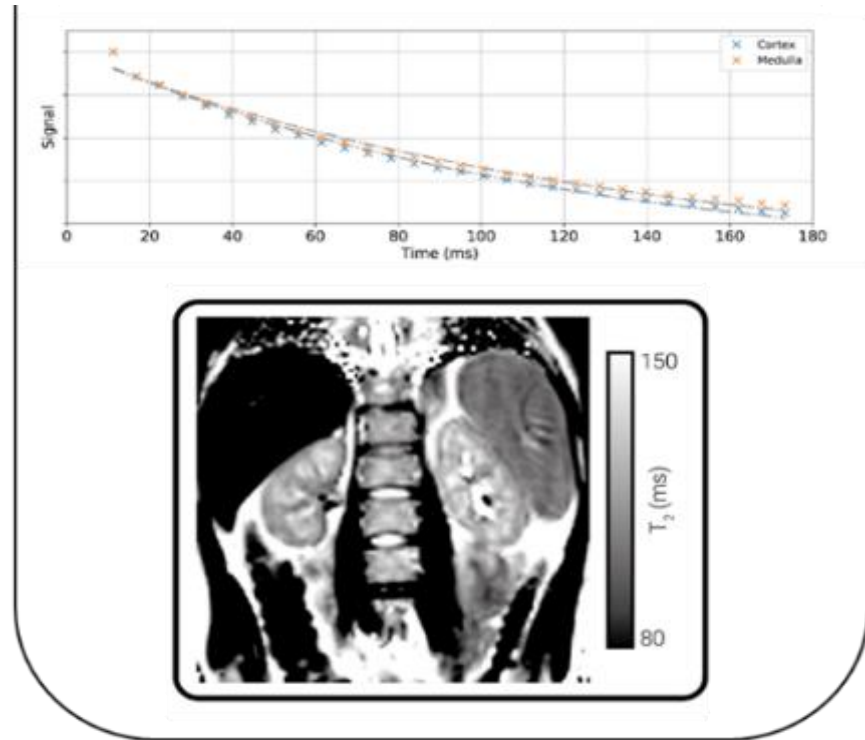
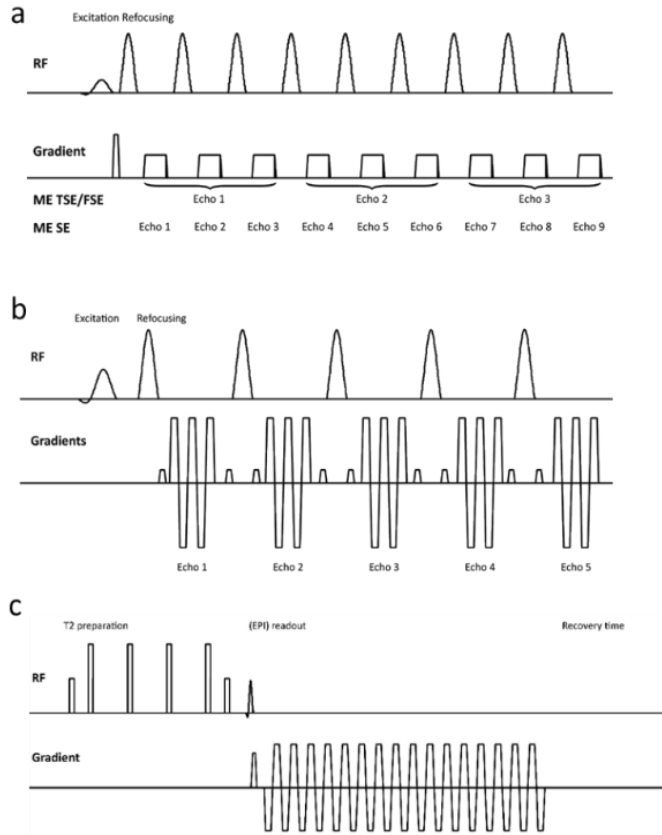
D Example T1 maps



# T2 mapping

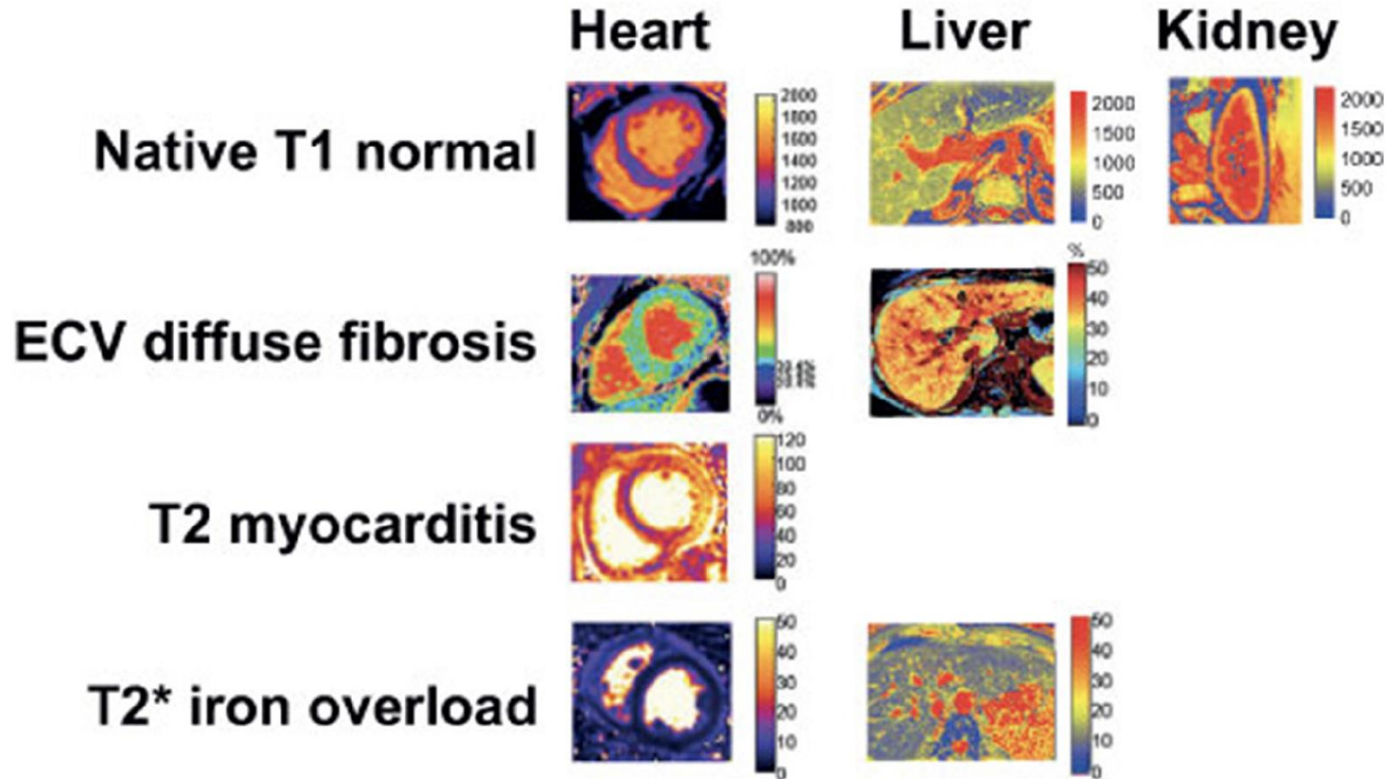


# Renal T2 mapping acquisition schemes

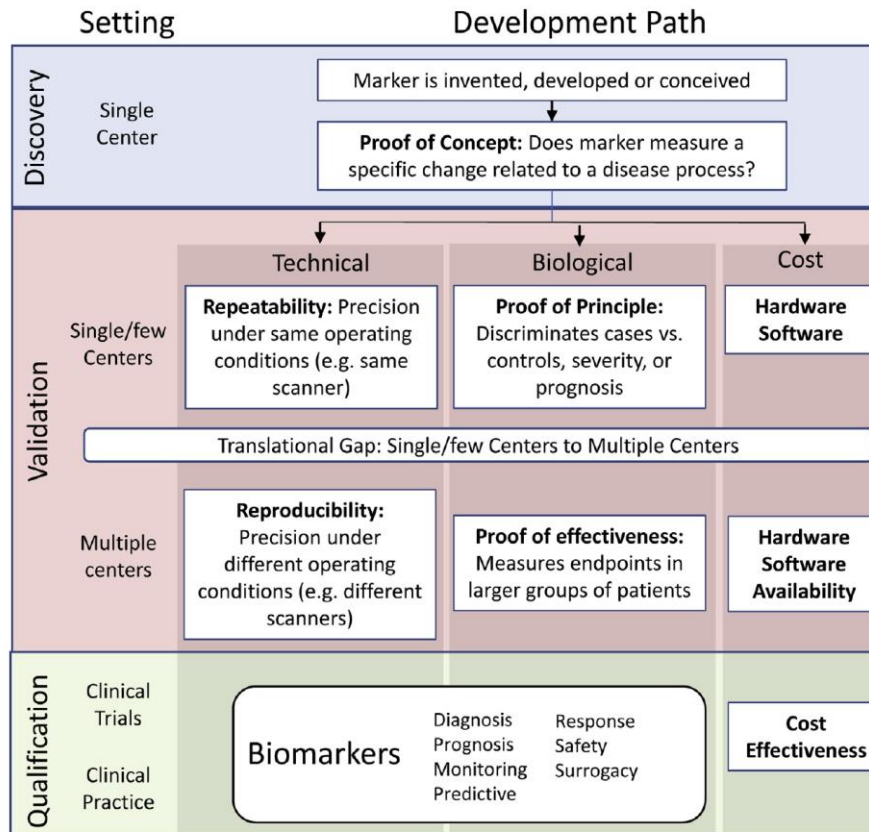




# T1 and T2 mapping: biomarkers?



# T1 and T2 mapping: biomarkers?



# Proof of concept - renal T1 mapping

## SCIENTIFIC REPORTS

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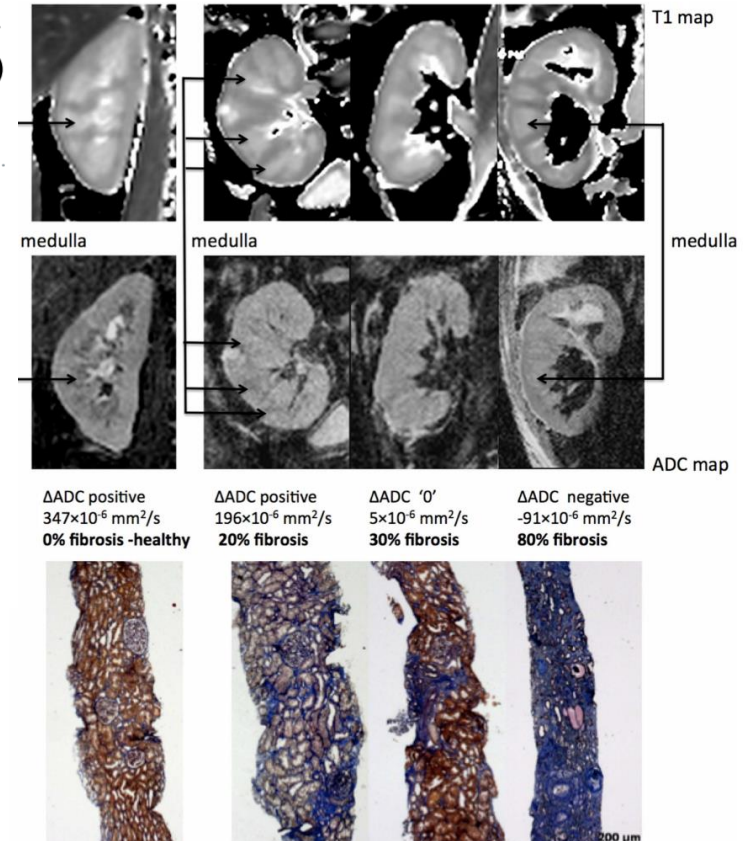
### New Magnetic Resonance Imaging Index for Renal Fibrosis Assessment: A Comparison between Diffusion-Weighted Imaging and T1 Mapping with Histological Validation

Received: 30 March 2016

Accepted: 29 June 2016

Published: 21 July 2016

I. Friedli<sup>1</sup>, L. A. Crowe<sup>1</sup>, L. Berchtold<sup>2</sup>, S. Moll<sup>3</sup>, K. Hadaya<sup>4</sup>, T. de Perrot<sup>1</sup>, C. Vesin<sup>5</sup>, P.-Y. Martin<sup>2</sup>, S. de Seigneux<sup>2</sup> & J.-P. Vallée<sup>1</sup>




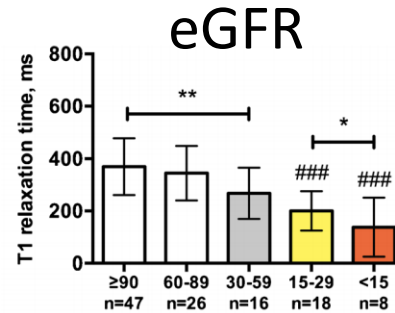
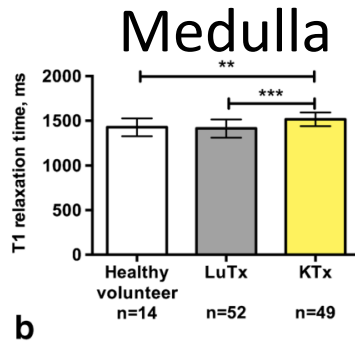
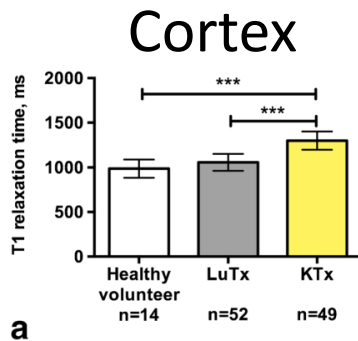
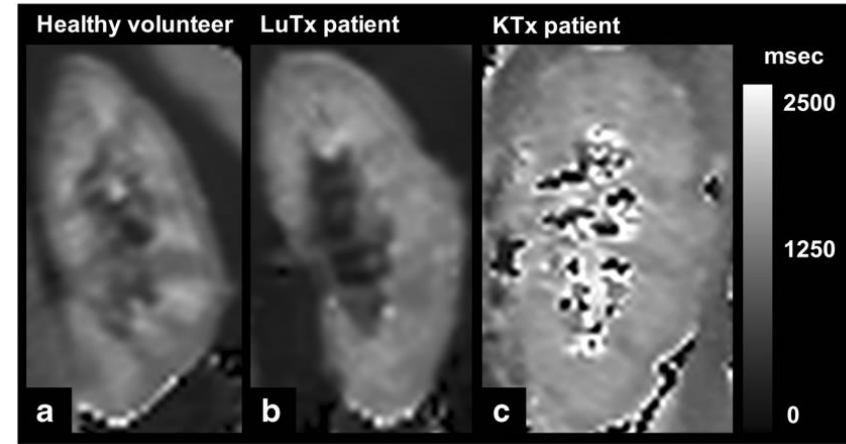
# Renal T1 mapping in transplant patients

Eur Radiol (2018) 28:44–50  
DOI 10.1007/s00330-017-4943-4

UROGENITAL

## Assessment of acute kidney injury with T1 mapping MRI following solid organ transplantation

Matti Peperhove<sup>1</sup> · Van Dai Vo Chieu<sup>1</sup> · Mi-Sun Jang<sup>2</sup> · Marcel Gutberlet<sup>1</sup> ·  
Dagmar Hartung<sup>1</sup> · Susanne Tewes<sup>1</sup> · Gregor Warnecke<sup>3</sup> · Christiane Fegbeutel<sup>3</sup> ·  
Axel Haverich<sup>3</sup> · Wilfried Gwinner<sup>2</sup> · Frank Lehner<sup>4</sup> · Jan Hinrich Bräsen<sup>5</sup> ·  
Hermann Haller<sup>2</sup> · Frank Wacker<sup>1</sup> · Faikah Gueler<sup>2</sup> · Katja Hueper<sup>1</sup> 

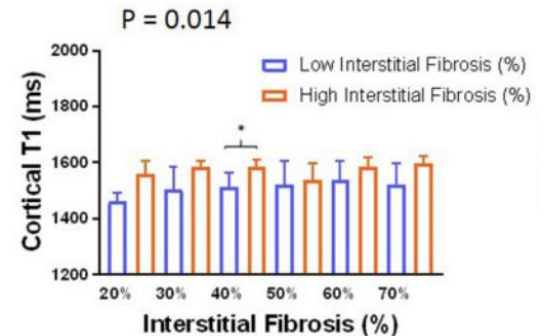
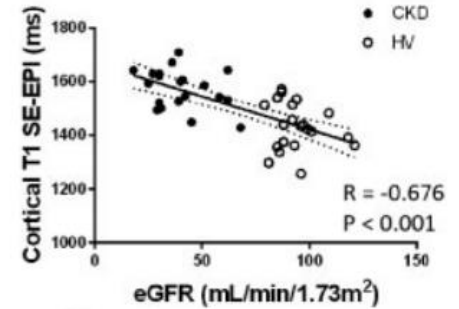
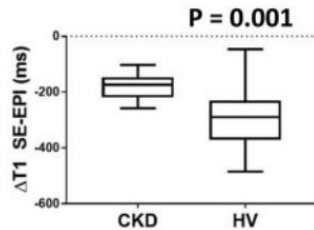
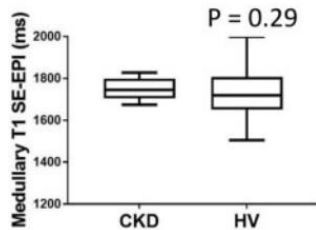
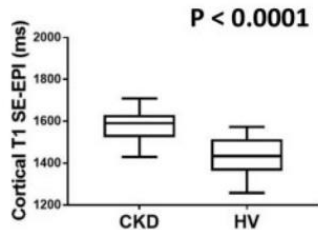


# Renal T1 mapping in CKD

## Quantitative assessment of renal structural and functional changes in chronic kidney disease using multi-parametric magnetic resonance imaging

Charlotte E. Buchanan<sup>1</sup>, Huda Mahmoud<sup>2</sup>, Eleanor F. Cox<sup>1</sup>, Thomas McCulloch<sup>3</sup>, Benjamin L. Prestwich<sup>1</sup>, Maarten W. Taal<sup>2</sup>, Nicholas M. Selby<sup>2</sup> and Susan T. Francis<sup>1</sup>

<sup>1</sup>Sir Peter Mansfield Imaging Centre, School of Physics and Astronomy, University of Nottingham, Nottingham, UK, <sup>2</sup>Centre for Kidney Research and Innovation, University of Nottingham, Royal Derby Hospital Campus, Nottingham, UK and <sup>3</sup>Nottingham University Hospitals NHS Trust, Nottingham, UK



# Renal T1 mapping in IgA nephropathy

Graham-Brown et al. *BMC Nephrology* (2019) 20:256  
<https://doi.org/10.1186/s12882-019-1447-2>

BMC Nephrology

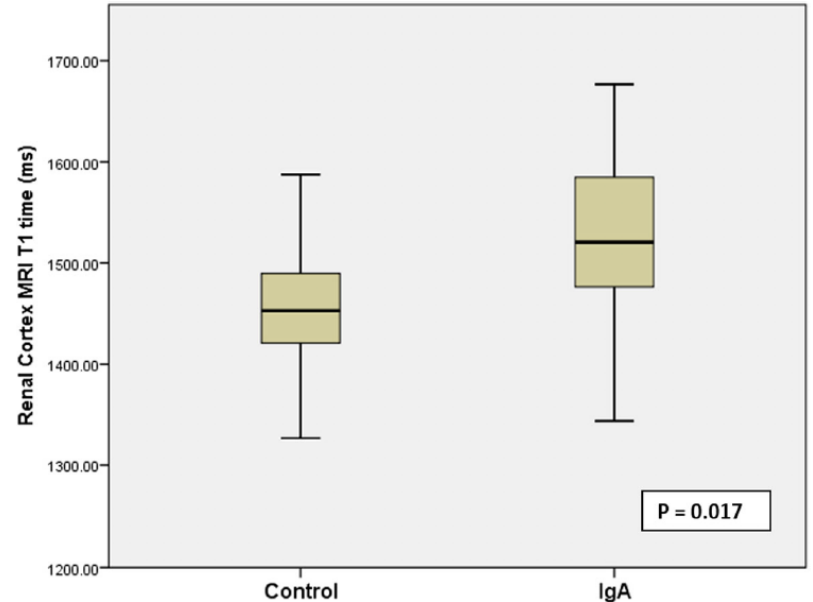
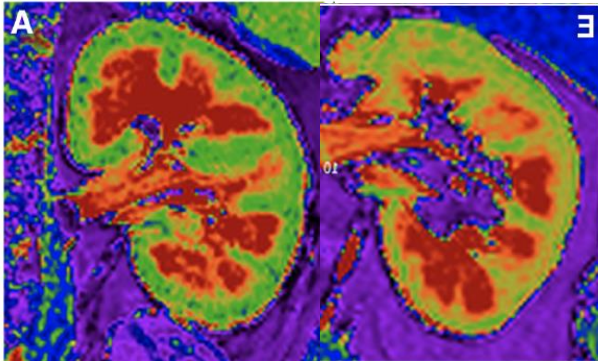
RESEARCH ARTICLE

Open Access

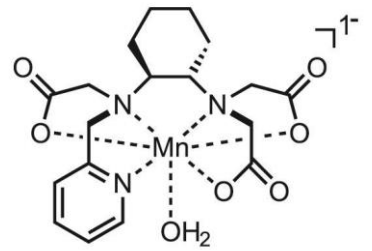
## Association between native T1 mapping of the kidney and renal fibrosis in patients with IgA nephropathy



M. P. Graham-Brown<sup>1,2</sup>, A. Singh<sup>3</sup>, J. Wormleighton<sup>3</sup>, N. J. Brunskill<sup>1,2</sup>, G. P. McCann<sup>3</sup>, J. Barratt<sup>1,2</sup>, J. O. Burton<sup>1,2</sup> and G. Xu<sup>1,2\*</sup>

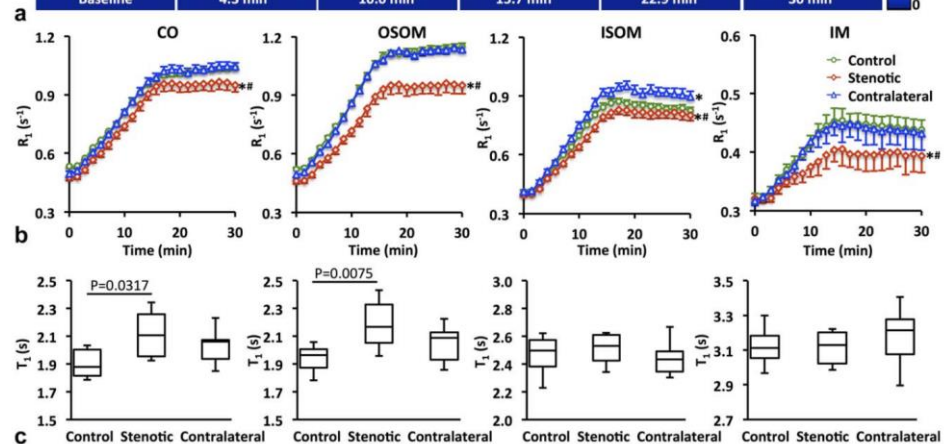
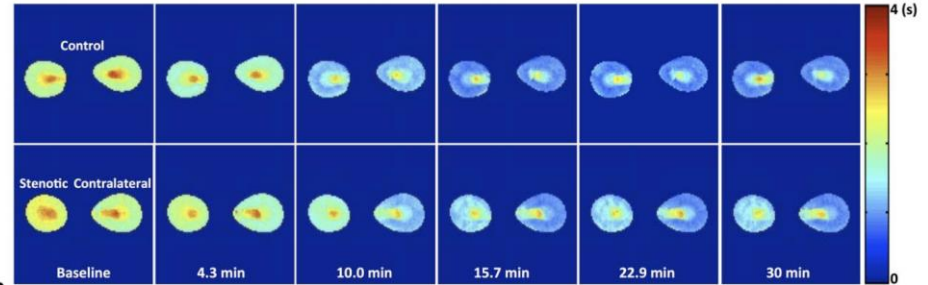
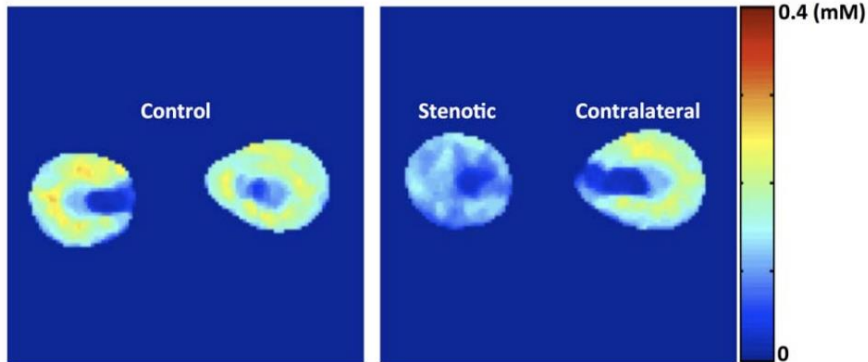


# Renal T1 mapping in viability imaging?

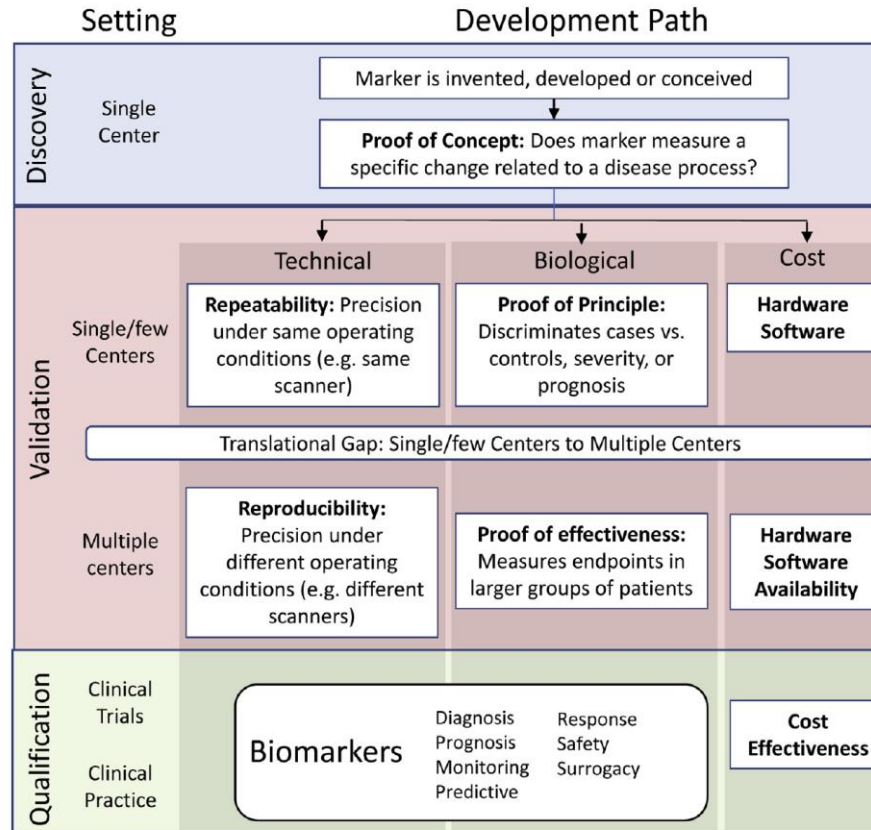


## A Rapid T<sub>1</sub> Mapping Method for Assessment of Murine Kidney Viability Using Dynamic Manganese-Enhanced Magnetic Resonance Imaging

Kai Jiang,<sup>1</sup> Hui Tang,<sup>1</sup> Prasanna K. Mishra,<sup>2</sup> Slobodan I. Ma and Lilach O. Lerman<sup>1\*</sup>



# Biomarker development framework





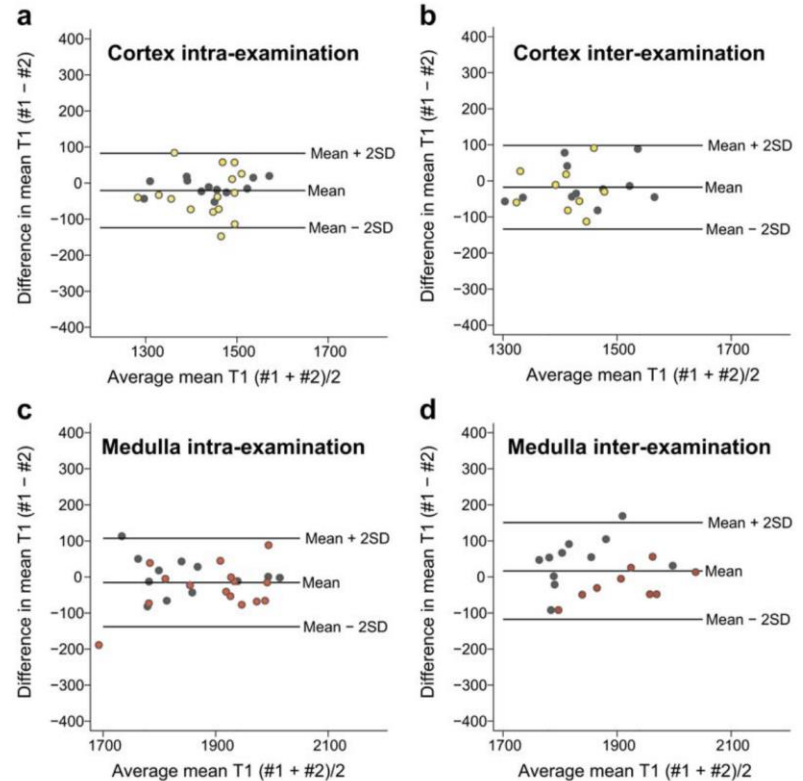
# Repeatability of renal T1 mapping

**TABLE 3** | Intra subject repeatability for the multiparametric MRI measures in healthy participants.

Parameter	Repeatability measures			
	CoV (%)	ICC	Number of subjects	Number of visits
Single renal artery flow	14.4 ± 4.3	0.844	11	3
Single renal vein flow	18.8 ± 10.3	0.649	11	3
Total perfusion to single kidney	14.9 ± 3.8	0.611	10	3
Cortex perfusion	9.3 ± 4.4	0.801	11	3
Cortex T <sub>1</sub> (at 3 T) SE-EPI	2.0 ± 1.5	0.848	9	2
bFFE	2.3 ± 1.3	0.616	11	3
Medulla T <sub>1</sub> (at 3 T) SE-EPI	1.8 ± 1.5	0.997	9	2
bFFE	2.9 ± 2.4	0.239	11	3
Cortex T <sub>2</sub> <sup>*</sup> (at 3 T)	4.1 ± 3.0	0.718	4	2
Cortex ADC	2.9 ± 2.0	0.745	10	3
Cortex D	9.5 ± 4.8	0.307	10	3
Cortex D*	38.8 ± 19.6	0.210	10	3
Cortex f <sub>p</sub>	21.5 ± 10.6	0.102	10	3
Total kidney volume	4.2 ± 2.6	0.985	11	3

CoV, coefficient of variation; ICC, intra class correlation; T<sub>1</sub>, longitudinal relaxation time; SE-EPI, spin echo-echo planar imaging; bFFE, balanced fast field echo; T<sub>2</sub><sup>\*</sup>, transverse relaxation time; ADC, apparent diffusion coefficient; D, pure diffusion coefficient; D\*, pseudodiffusion coefficient; f<sub>p</sub>, perfusion fraction.

Cox et. al. fphys. 2017



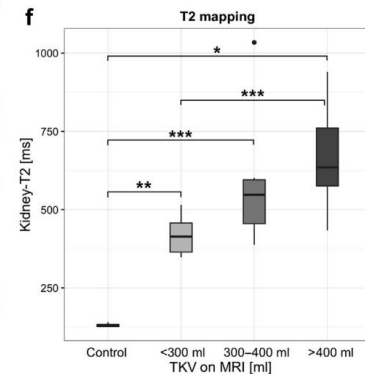
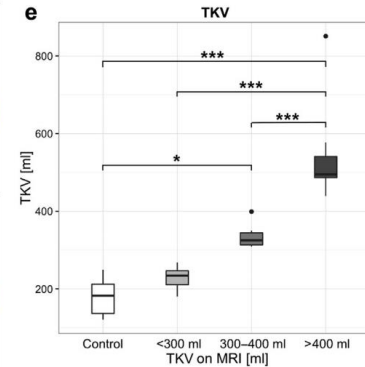
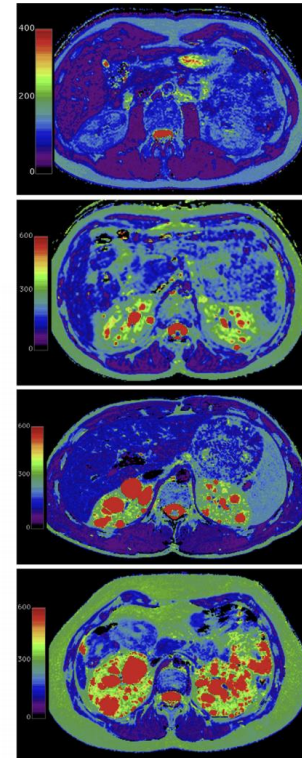
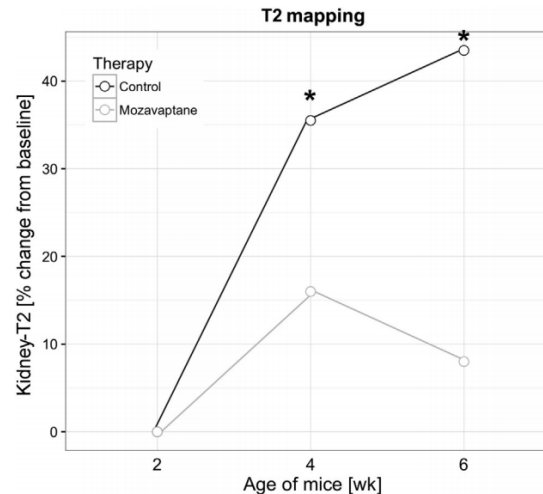
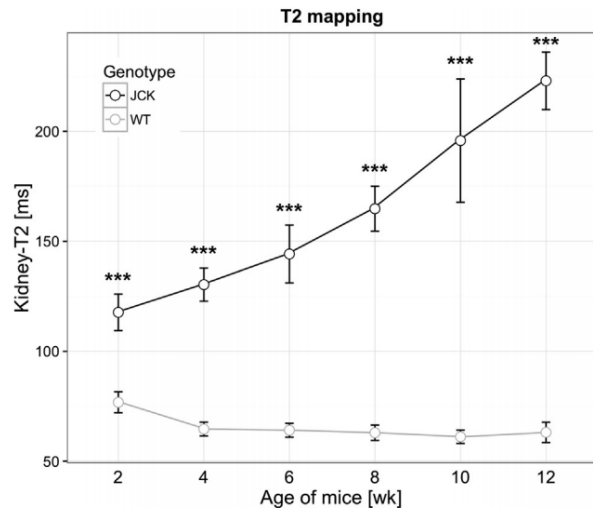
Dekkers et. al. JMRI 2018

# So what about T2 mapping?



## Magnetic resonance T2 mapping and diffusion-weighted imaging for early detection of cystogenesis and response to therapy in a mouse model of polycystic kidney disease

Mareike Franke<sup>1,2,8</sup>, Bettina Baeßler<sup>1,8</sup>, Jan Vechtel<sup>1</sup>, Claudia Dafinger<sup>3,4</sup>, Martin Höhne<sup>3,5</sup>, Lori Borgal<sup>3</sup>, Heike Göbel<sup>5,6</sup>, Friederike Koerber<sup>1</sup>, David Maintz<sup>1</sup>, Thomas Benzing<sup>3,5,7</sup>, Bernhard Schermer<sup>3,5,7</sup> and Thorsten Persigehl<sup>1</sup>

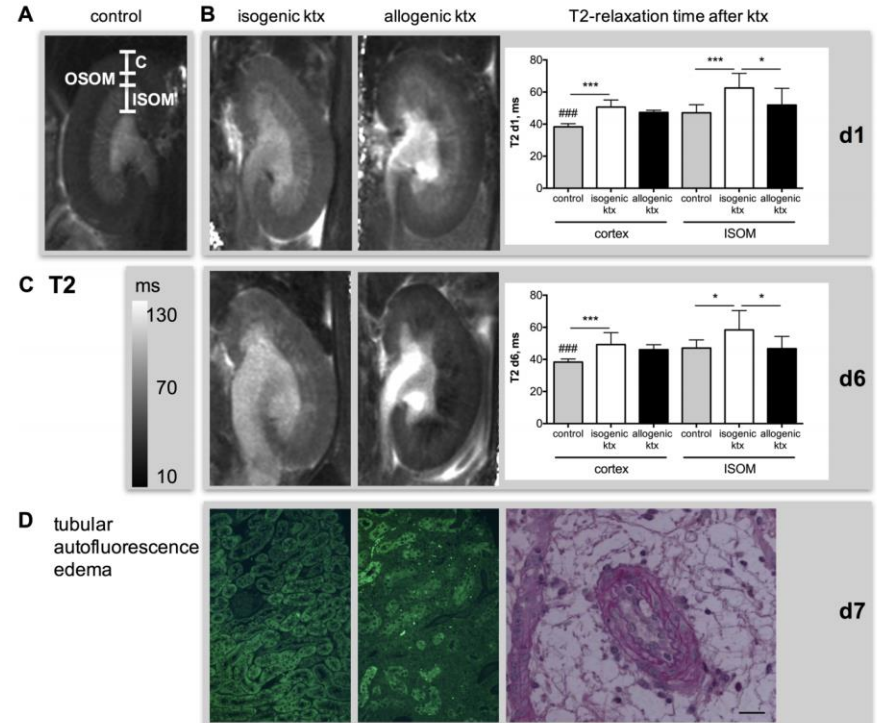
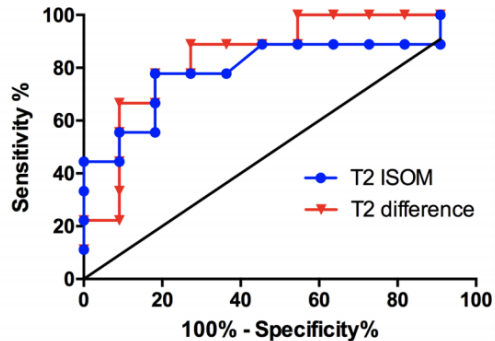


# T2 mapping after renal transplantation

RESEARCH ARTICLE

## Multiparametric Functional MRI: Non-Invasive Imaging of Inflammation and Edema Formation after Kidney Transplantation in Mice

Katja Hueper<sup>1\*</sup>, Marcel Gutberlet<sup>1</sup>, Jan Hinrich Bräsen<sup>2</sup>, Mi-Sun Jang<sup>3</sup>, Anja Thorenz<sup>3</sup>, Rongjun Chen<sup>3,6</sup>, Barbara Hertel<sup>3</sup>, Amelie Barrmeyer<sup>1</sup>, Martina Schmidbauer<sup>1</sup>, Martin Meier<sup>4</sup>, Sibylle von Vietinghoff<sup>3</sup>, Abedalrazag Khalifa<sup>2</sup>, Dagmar Hartung<sup>1</sup>, Hermann Haller<sup>3</sup>, Frank Wacker<sup>1</sup>, Song Rong<sup>3,5</sup>, Faikah Gueler<sup>3</sup>



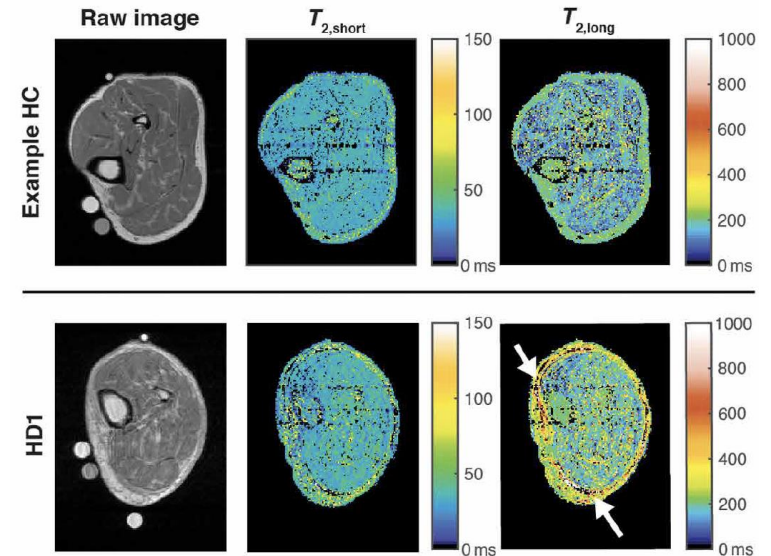
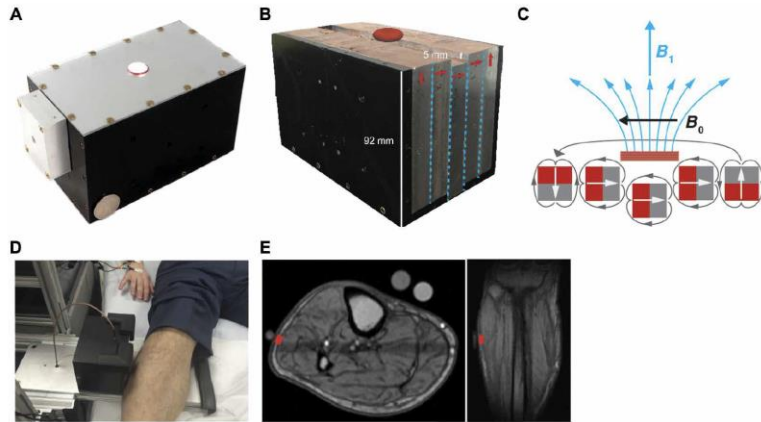
# New kid on the block: 'bed-side T2 relaxometry' in dialysis patients

SCIENCE TRANSLATIONAL MEDICINE | RESEARCH ARTICLE

## BIOENGINEERING

### Fluid assessment in dialysis patients by point-of-care magnetic relaxometry

Lina A. Colucci<sup>1,2</sup>, Kristin M. Corapi<sup>3</sup>, Matthew Li<sup>1,2</sup>, Xavier Vela Parada<sup>3</sup>, Andrew S. Allegretti<sup>3</sup>, Herbert Y. Lin<sup>3</sup>, Dennis A. Ausiello<sup>3</sup>, Matthew S. Rosen<sup>4,5</sup>, Michael J. Cima<sup>2,6\*</sup>



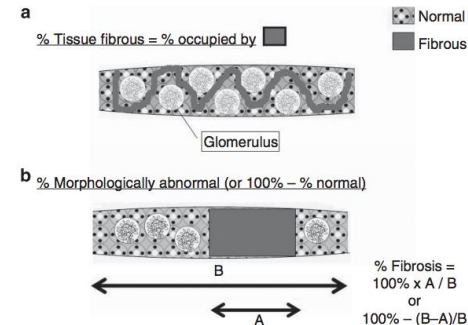
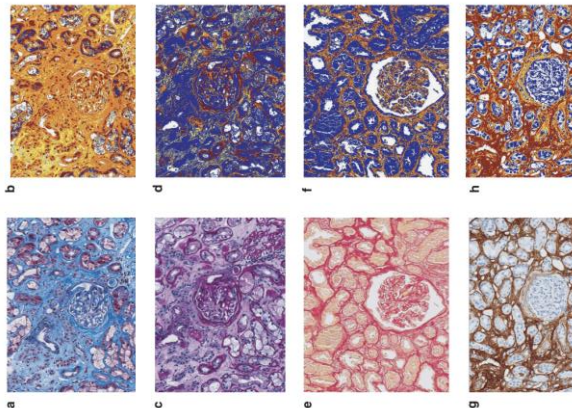
# Remaining challenges for renal T1 & T2 mapping

- ‘Gold standard’,
- Inaccuracy or imprecision of reference method
  
- Inter-scanner variability?
- Lack of scan protocol harmonization -> PARENCHIMA
- Normal values?
  
- Diagnostic value yet to be determined
- Cost-effectiveness?

## What is the best way to measure renal fibrosis?: A pathologist's perspective

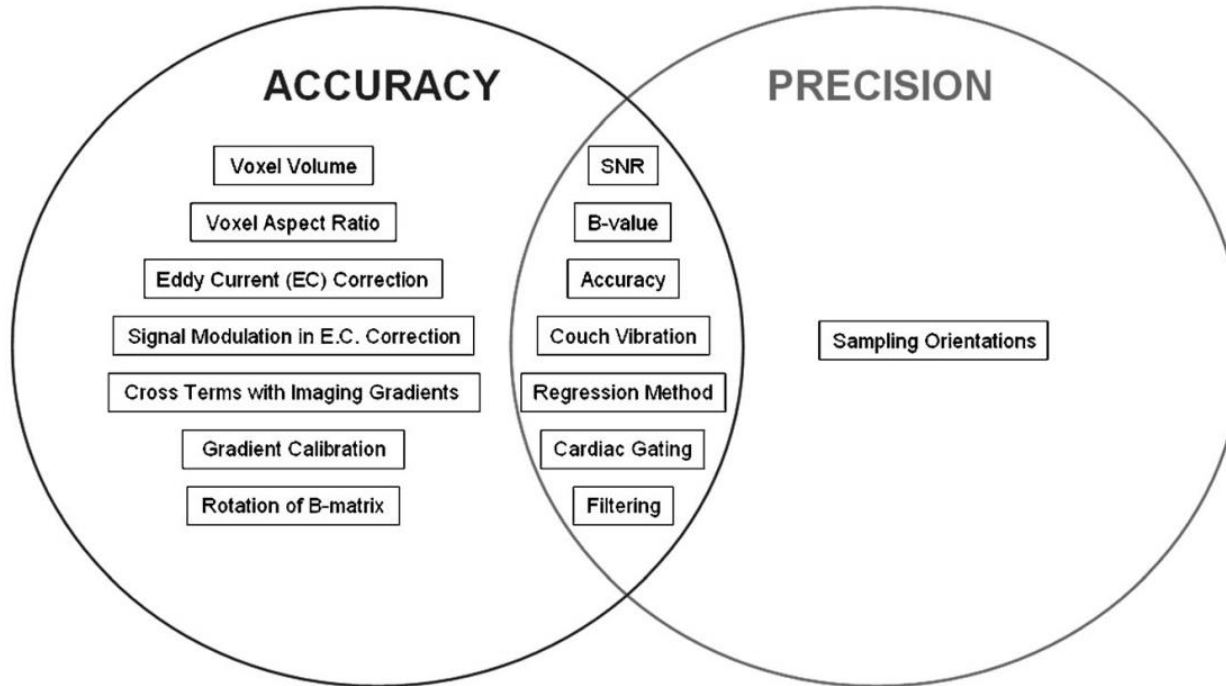
Alton B. Farris<sup>1</sup> and Charles E. Alpers<sup>2</sup>

<sup>1</sup>Department of Pathology and Laboratory Medicine, Emory University, Atlanta, Georgia, USA and <sup>2</sup>Department of Pathology, University of Washington, Seattle, Washington, USA



**Figure 2 | Characterization of patterns of renal fibrosis.** Percent interstitial fibrosis (% IF) can be conceptually thought of in at least two ways: (a) percent of tissue occupied by fibrous tissue and (b) percent of tissue morphologically abnormal. The cartoon depicts a collagen III immunohistochemistry stain in which the chromogen stains fibrosis.

# Factors affecting accuracy and precision



# Mind the Gap

Setting

Development Path



## Magnetic Resonance Materials in Physics, Biology and Medicine

Manuscript - MAGMA special issue - Consensus-based technical recommendations for clinical translation of renal T1 and T2 mapping MRI  
–Manuscript Draft–

Manuscript Number:	
Full Title:	Manuscript - MAGMA special issue - Consensus-based technical recommendations for clinical translation of renal T1 and T2 mapping MRI
Article Type:	Original Paper

	conditions (e.g. different scanners)	target groups of patients	<b>Availability</b>
--	--------------------------------------	---------------------------	---------------------



**Thank you for your attention**

Email: [i.a.dekkers@lumc.nl](mailto:i.a.dekkers@lumc.nl)

Twitter: [Dekkers\\_Ilona](https://twitter.com/Dekkers_Ilona) 