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

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

T1 values

at 3T: 1403 ± 76 | 1604 ± 98 ms

Kidney

Heart

Liver

T1 mapping

$M_z$ follows an exponential recovery, recovering toward its equilibrium value $M_0$ with a time constant T1.

$63\% M_0$
Consensus-based technical recommendations for clinical translation of renal T1 and T2 mapping MRI. PARENCHIMA. MAGMA submitted.
T2 mapping

Wolf M et al. NDT. 2018
Renal T2 mapping acquisition schemes

Consensus-based technical recommendations for clinical translation of renal T1 and T2 mapping MRI. PARENCHIMA. MAGMA submitted
T1 and T2 mapping: biomarkers?

Dekkers IA and Lamb HJ. Br J Radiol. 2018
T1 and T2 mapping: biomarkers?

European Society of Radiology. Insights into Imaging. 2013; HARNESS. Alzheimer’s & Dementia. 2019
New Magnetic Resonance Imaging Index for Renal Fibrosis Assessment: A Comparison between Diffusion-Weighted Imaging and T1 Mapping with Histological Validation

Renal T1 mapping in transplant patients

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

Matti Peperhoffe1, Van Dai Vo Chieu1, Mi-Sun Jang2, Marcel Gutberlet1, Dagmar Hartung1, Susanne Tewes1, Gregor Warnecke3, Christiane Fegbeutel3, Axel Haverich3, Wilfried Gwinner2, Frank Lehner4, Jan Hinrich Bräsen5, Hermann Haller3, Frank Wacker1, Faikah Gueler5, Katja Hueper1

Cortex

![Cortex Image]

Medulla

![Medulla Image]

eGFR

![eGFR Image]
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. Buchanan¹, Huda Mahmoud², Eleanor F. Cox¹, Thomas McCulloch³, Benjamin L. Prestwich¹, Maarten W. Taal², Nicholas M. Selby² and Susan T. Francis¹

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

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

M. P. Graham-Brown1,2, A. Singh3, J. Wormleighton3, N. J. Brunskill1,2, G. P. McCann3, J. Barratt1,2, J. O. Burton1,2 and G. Xu1,2

P = 0.017
Renal T1 mapping in viability imaging?


Kai Jiang,$^1$ Hui Tang,$^1$ Prasanna K. Mishra,$^2$ Slobodan I. Ma and Lilach O. Lerman$^1$*

![Diagram showing T1 mapping results](image)
Repeatability of renal T1 mapping

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

<table>
<thead>
<tr>
<th>Parameter</th>
<th>CoV (%)</th>
<th>ICC</th>
<th>Number of subjects</th>
<th>Number of visits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single renal artery flow</td>
<td>14.4 ± 4.3</td>
<td>0.844</td>
<td>11</td>
<td>3</td>
</tr>
<tr>
<td>Single renal vein flow</td>
<td>18.8 ± 10.3</td>
<td>0.649</td>
<td>11</td>
<td>3</td>
</tr>
<tr>
<td>Total perfusion to single kidney</td>
<td>14.9 ± 3.8</td>
<td>0.611</td>
<td>10</td>
<td>3</td>
</tr>
<tr>
<td>Cortex perfusion</td>
<td>9.3 ± 4.4</td>
<td>0.801</td>
<td>11</td>
<td>3</td>
</tr>
<tr>
<td>Cortex T1 (at 3 T) SE-EPI</td>
<td>2.0 ± 1.5</td>
<td>0.848</td>
<td>9</td>
<td>2</td>
</tr>
<tr>
<td>bFFE</td>
<td>2.3 ± 1.3</td>
<td>0.616</td>
<td>11</td>
<td>3</td>
</tr>
<tr>
<td>Medulla T1 (at 3 T) SE-EPI</td>
<td>1.8 ± 1.5</td>
<td>0.997</td>
<td>9</td>
<td>2</td>
</tr>
<tr>
<td>bFFE</td>
<td>2.9 ± 2.4</td>
<td>0.239</td>
<td>11</td>
<td>3</td>
</tr>
<tr>
<td>Cortex T2* (at 3 T)</td>
<td>4.1 ± 3.0</td>
<td>0.718</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>Cortex ADC</td>
<td>2.9 ± 2.0</td>
<td>0.745</td>
<td>10</td>
<td>3</td>
</tr>
<tr>
<td>Cortex D</td>
<td>9.5 ± 4.8</td>
<td>0.307</td>
<td>10</td>
<td>3</td>
</tr>
<tr>
<td>Cortex D*</td>
<td>38.8 ± 19.6</td>
<td>0.210</td>
<td>10</td>
<td>3</td>
</tr>
<tr>
<td>Cortex f0</td>
<td>21.5 ± 10.6</td>
<td>0.102</td>
<td>10</td>
<td>3</td>
</tr>
<tr>
<td>Total kidney volume</td>
<td>4.2 ± 2.6</td>
<td>0.985</td>
<td>11</td>
<td>3</td>
</tr>
</tbody>
</table>

CoV, coefficient of variation; ICC, intra class correlation; T1, longitudinal relaxation time; SE-EPI, spin echo-echo planar imaging; bFFE, balanced fast field echo; T2*, transverse relaxation time; ADC, apparent diffusion coefficient; D, pure diffusion coefficient; D*, pseudodiffusion coefficient; f0, 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, Bettina Baeßler, Jan Vechtel, Claudia Dafinger, Martin Höhne, Lori Borgal, Heike Göbel, Friederike Koerber, David Maintz, Thomas Benzing, Bernhard Schermer and Thorsten Persieghl
Multiparametric Functional MRI: Non-Invasive Imaging of Inflammation and Edema Formation after Kidney Transplantation in Mice

Katja Hueper¹*, Marcel Gutberlet¹, Jan Hinrich Bräsen², Mi-Sun Jang³, Anja Thorenz³, Rongjun Chen³,⁶, Barbara Hertel³, Amelie Barrmeyer¹, Martina Schmidbauer¹, Martin Meier⁴, Sibylle von Vietinghoff³, Abedalrazag Khalifa², Dagmar Hartung¹, Hermann Haller³, Frank Wacker¹, Song Rong³,⁵, Falkah Gueler³

T2 mapping after renal transplantation

RESEARCH ARTICLE

A

B

C

D

T2 relaxation time after ktx

0 20 40 60 80 100

Sensitivity %

100% - Specificity %

T2 ISOM

T2 difference

T2 mapping after renal transplantation

T2 mapping after renal transplantation

T2 mapping after renal transplantation

T2 mapping after renal transplantation

T2 mapping after renal transplantation

T2 mapping after renal transplantation

T2 mapping after renal transplantation

T2 mapping after renal transplantation

T2 mapping after renal transplantation

T2 mapping after renal transplantation

T2 mapping after renal transplantation

T2 mapping after renal transplantation
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. Colucci¹², Kristin M. Corapi³, Matthew Li¹², Xavier Vela Parada³, Andrew S. Allegretti³, Herbert Y. Lin³, Dennis A. Ausiello³, Matthew S. Rosen⁴⁵, Michael J. Cima²⁶*
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. Farris¹ and Charles E. Alpers²

¹Department of Pathology and Laboratory Medicine, Emory University, Atlanta, Georgia, USA and ²Department 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

ACCURACY
- Voxel Volume
- Voxel Aspect Ratio
- Eddy Current (EC) Correction
- Signal Modulation in E.C. Correction
- Cross Terms with Imaging Gradients
- Gradient Calibration
- Rotation of B-matrix

PRECISION
- SNR
- B-value
- Accuracy
- Couch Vibration
- Regression Method
- Cardiac Gating
- Filtering
- Sampling Orientations

Jones. Top Magn Reson Imaging 2010
Mind the Gap

Setting

Development Path

- Technical
- Biological
- Cost

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–

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conditions (e.g., different scanners)

| Target groups of patients | Availability |
Thank you for your attention

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