^{23}Na MRI

Armin M. Nagel

Professorship for metabolic and functional MR imaging

Institute of Radiology (Head: Prof. Michael Uder), University Hospital Erlangen, Germany

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FRIEDRICH-ALEXANDER UNIVERSITÄT ERLANGEN-NÜRNBERG
MEDIZINISCHE FAKULTÄT

Universitätsklinikum Erlangen

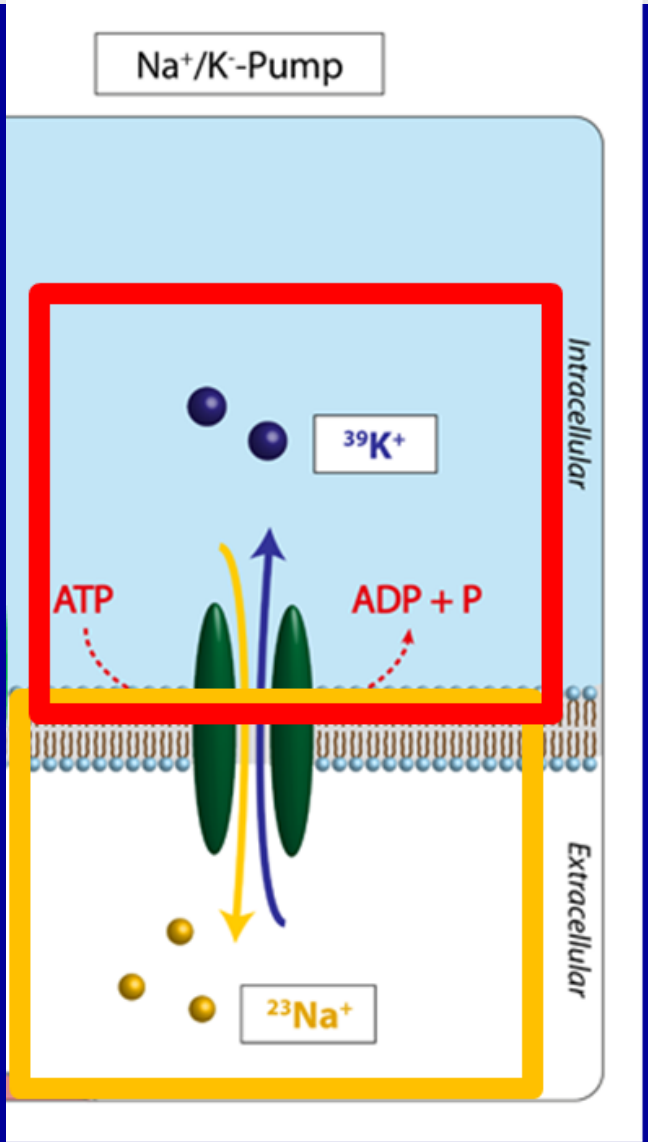
Imaging of Ions (Na^+, K^+)
Why?

- Function of Na^+/K^+-pump / cell viability
- Cell membrane potential

Ion	$C_{extrac.}$ (mM)	$C_{intrac.}$ (mM)	E_{ion} (mV)
K^+	3.5 - 5	140	-95
Na^+	145	10 - 15	+60

→ **Ion concentrations:** early marker in many disease processes

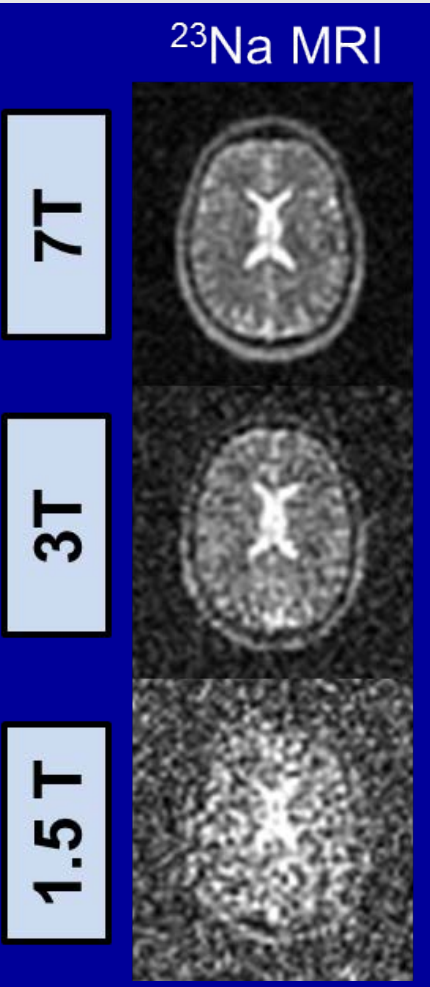
→ **Kidneys**:
control of electrolyte concentrations



Kline, Bauman, Gay. Physiologie. Thieme 2010

NMR Properties of ^{23}Na and ^{39}K

	^{23}Na	^{39}K	^{1}H
NMR-sensitivity [%]	9.3	0.05	100
concentration [M]	0.02 - 0.3	≈ 0.1	80
relative SNR	**0.01 - 0.1**	**≈ 10^{-3}**	**100**

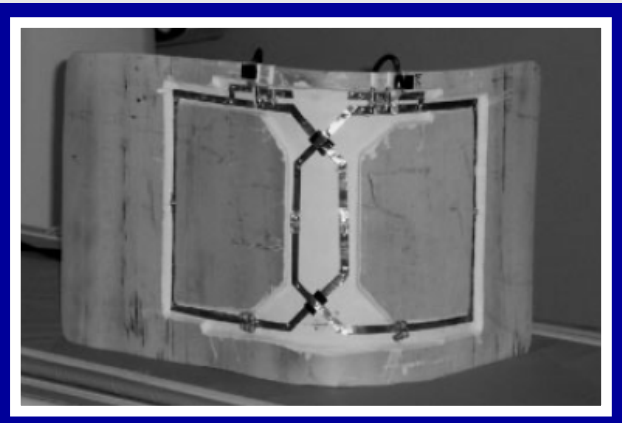


- UHF MRI[1]
- Pulse sequences[2]: SNR ↑ / TE ↓
- Dedicated hardware

1) Ladd et al. Prog. Nucl. Magn. Reson. Spectrosc. (2018)

2) Konstandin, Nagel. MAGMA (2014)

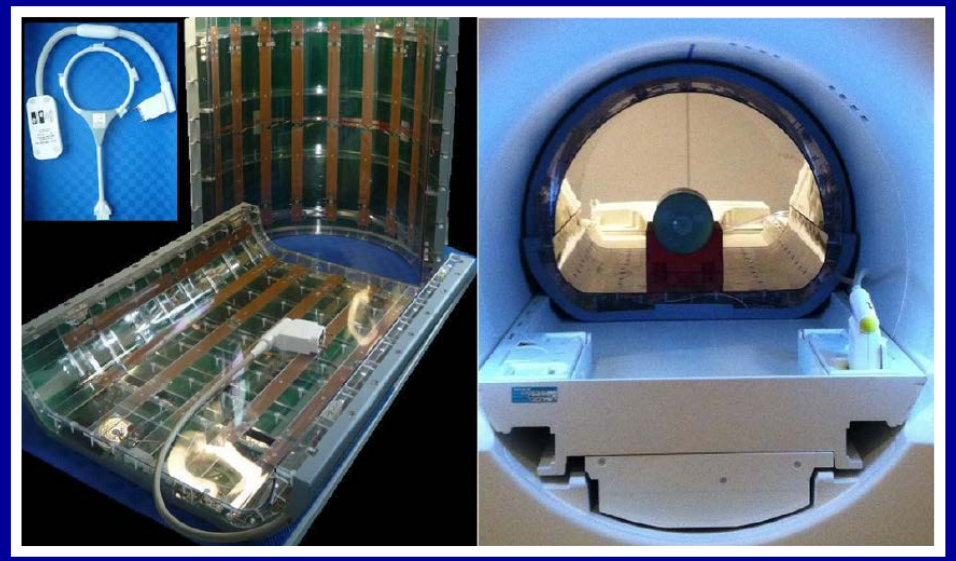
RF Coils for Renal ^{23}Na MRI



Maril et al. Magn Reson Med 2006

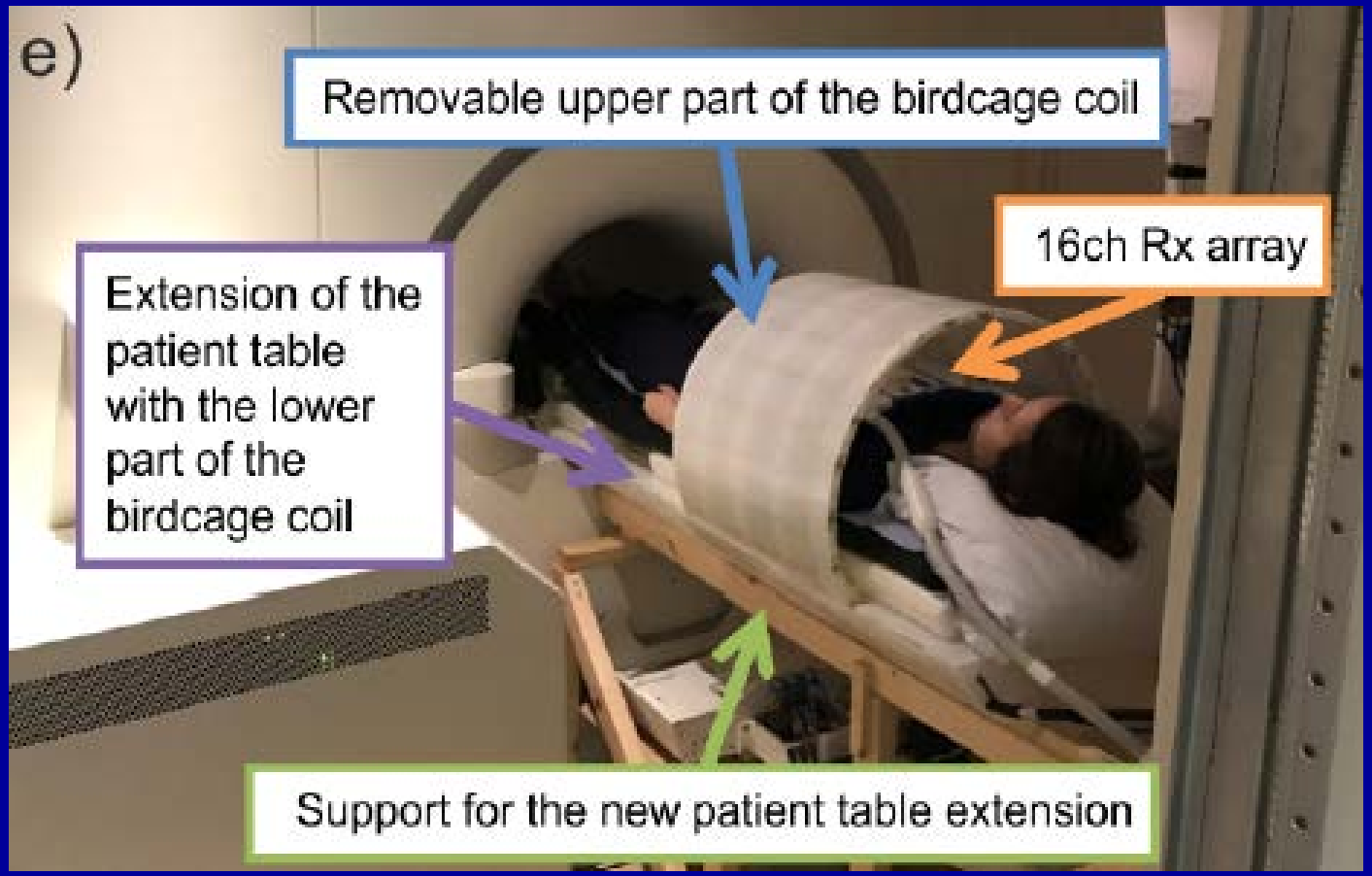
Platt et al. Magn Reson Med 2018

Böhmert et al. Magn Reson Med 2019



Wetterling et al. Phys Med Biol 2012

Whole-Body Transmit Coil and 16-Element Receive Array (^{31}P MRS)



Quintuple tuned body array

MetaScan Project/ UMC Utrecht

Valkovič et al. PLoS One 2017

Why MRI of Ion Concentrations?

- Blood samples?
  - > 1 billion examinitions per year

\+ cheap

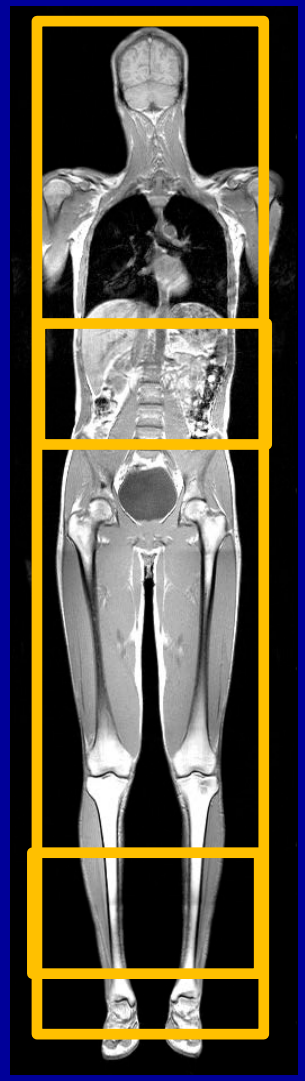
\+ fast

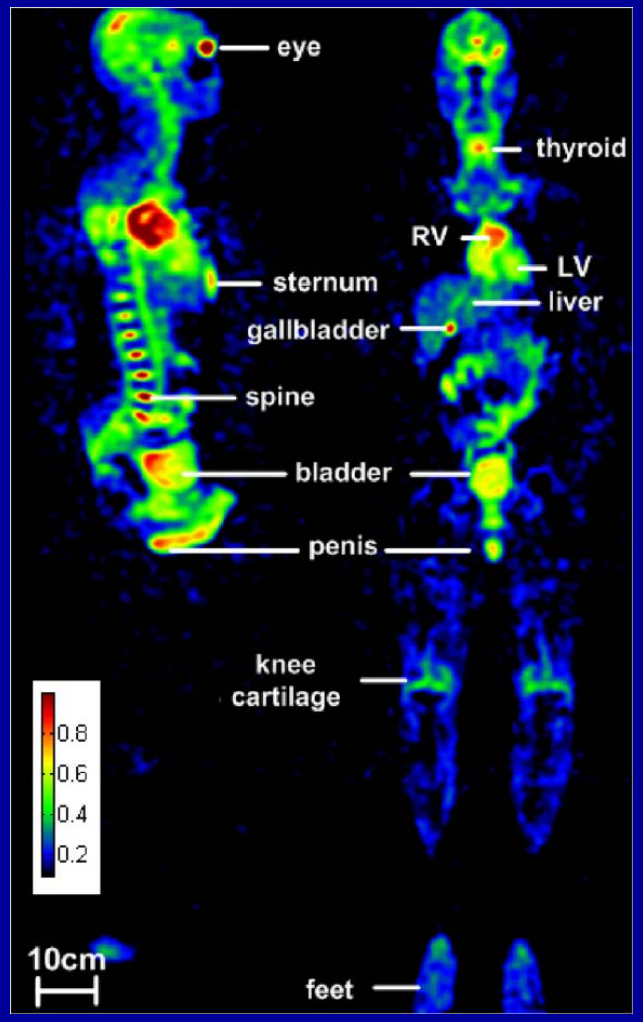
– *ex vivo*; only from extracellular body fluids (e.g. blood serum, urine, CSF)

– No information about intracellular or total tissue ion concentration

^{23}Na MRI
Renal Imaging/ Applications in Renal Diseases

- Direct Renal Imaging
- Effects of Renal Diseases on tissue Na^+ homeostasis





Wetterling et al. Phys Med Biol 2012

^{23}Na MRI
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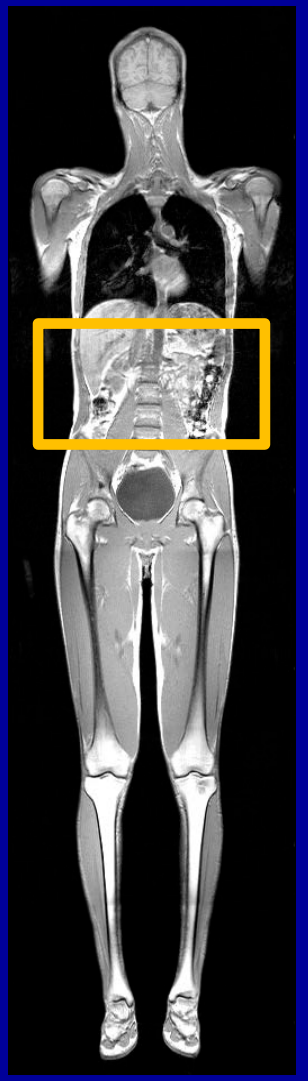
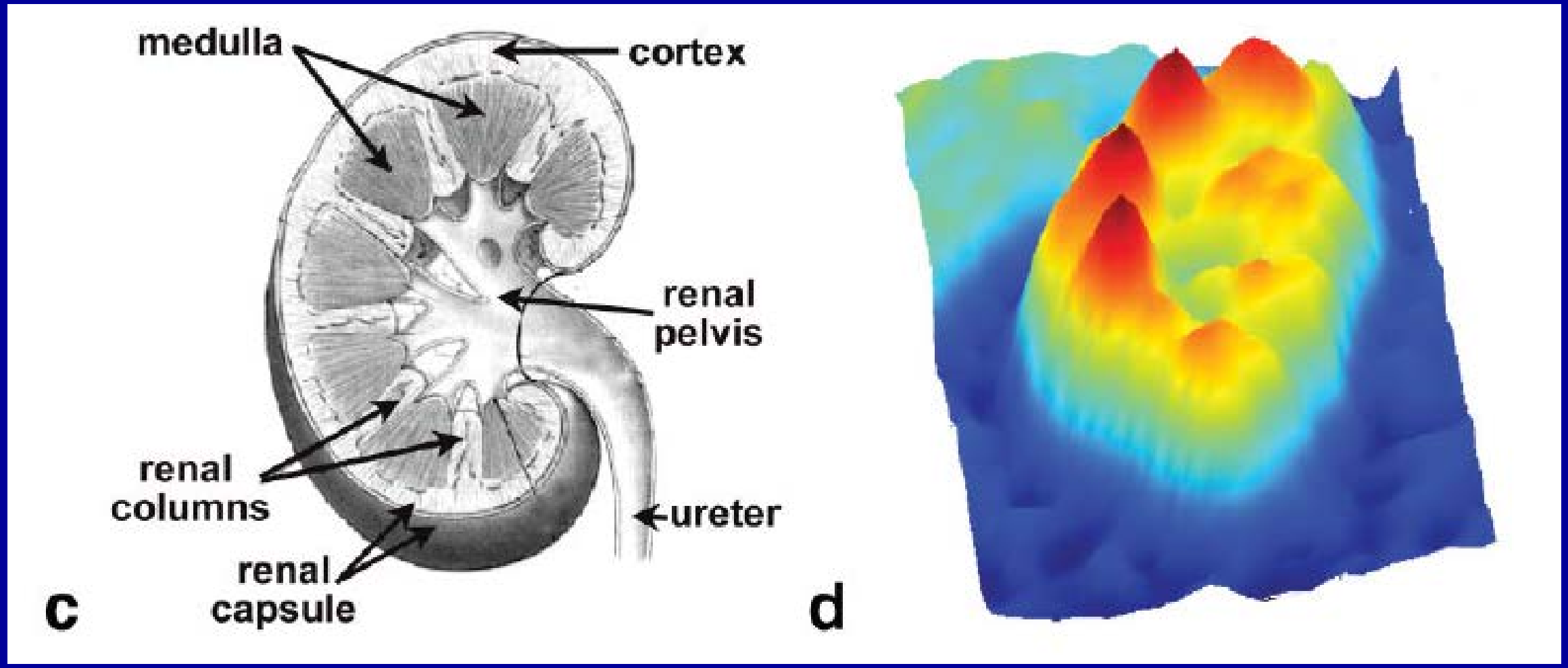


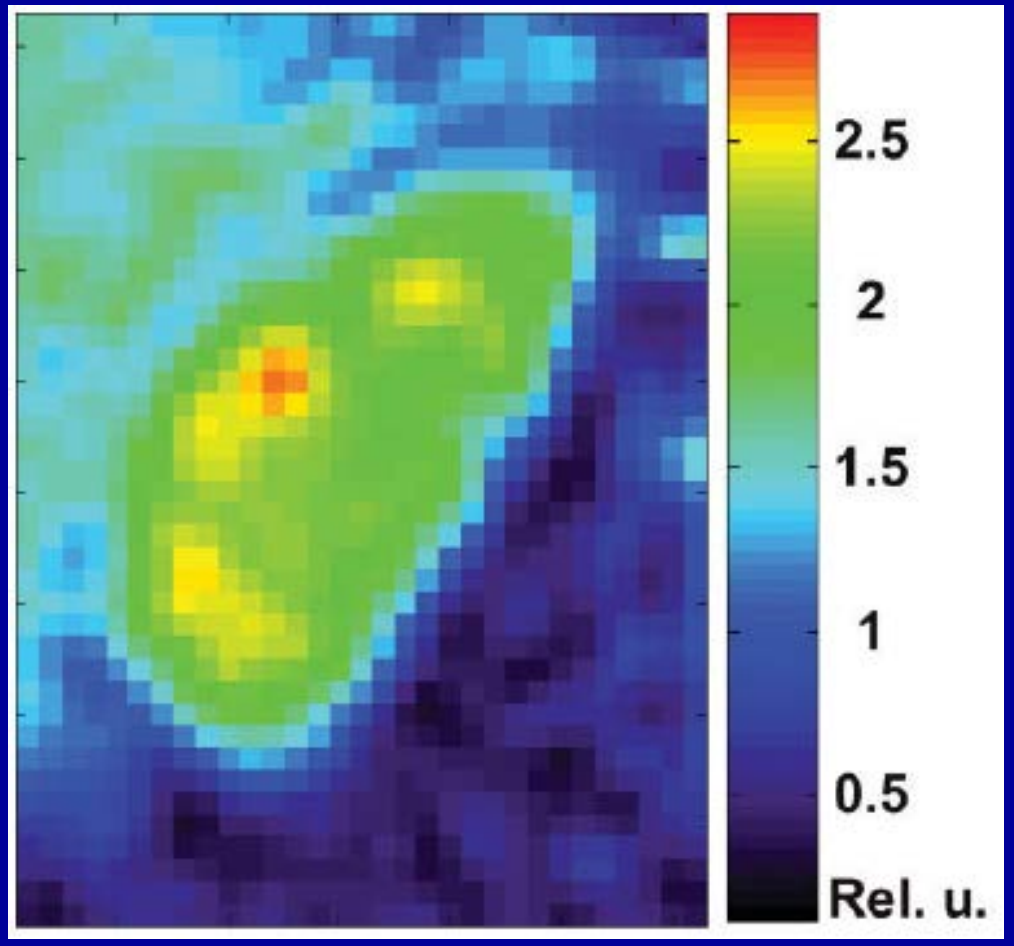
Renal ^{23}Na MRI
Concentration Gradient: From Cortex to Medulla



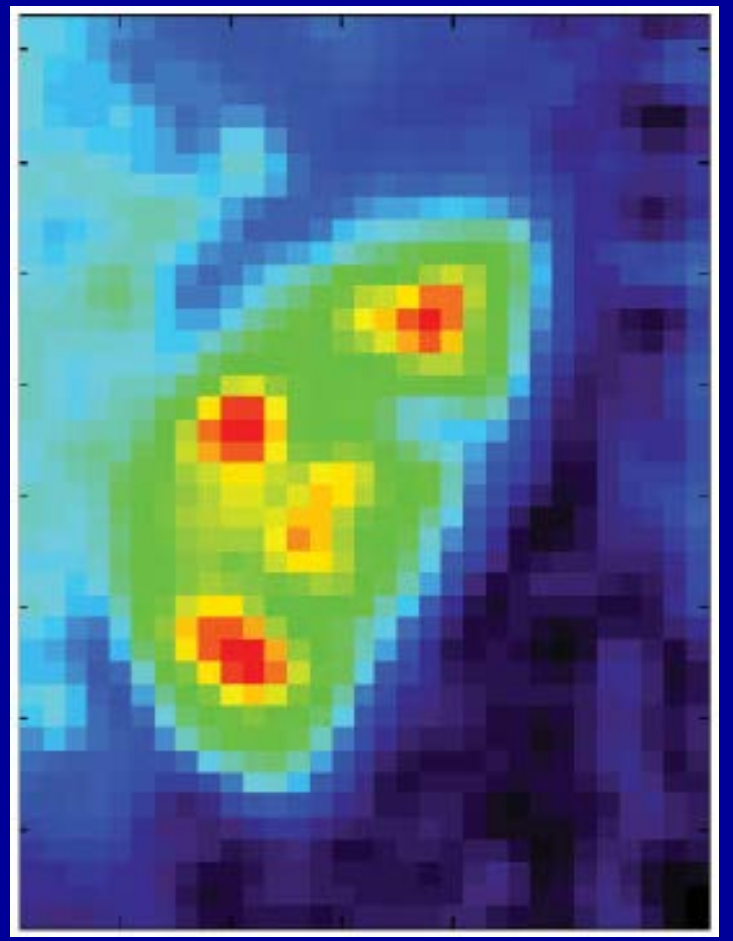
Maril et al. Magn Reson Med 2006

Renal ^{23}Na MRI

normal conditions

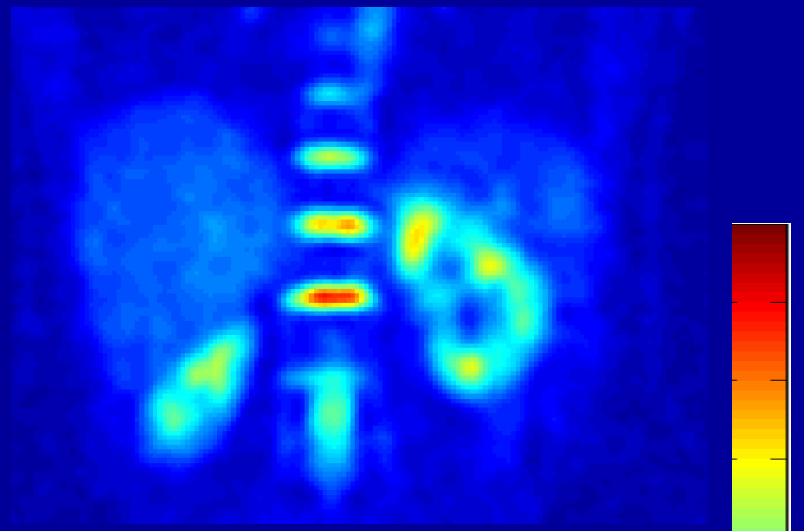


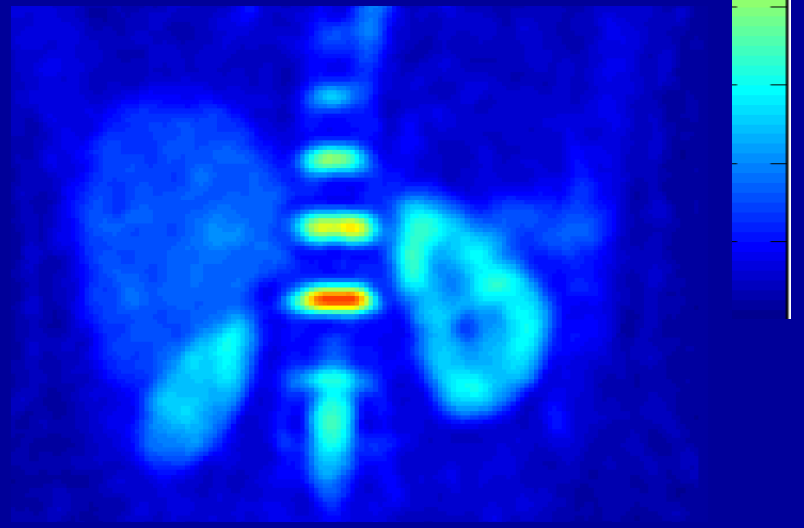
12h water depriviation



Maril et al. Magn Reson Med 2006

Renal ^{23}Na MRI
Water Deprivation vs. Water Load



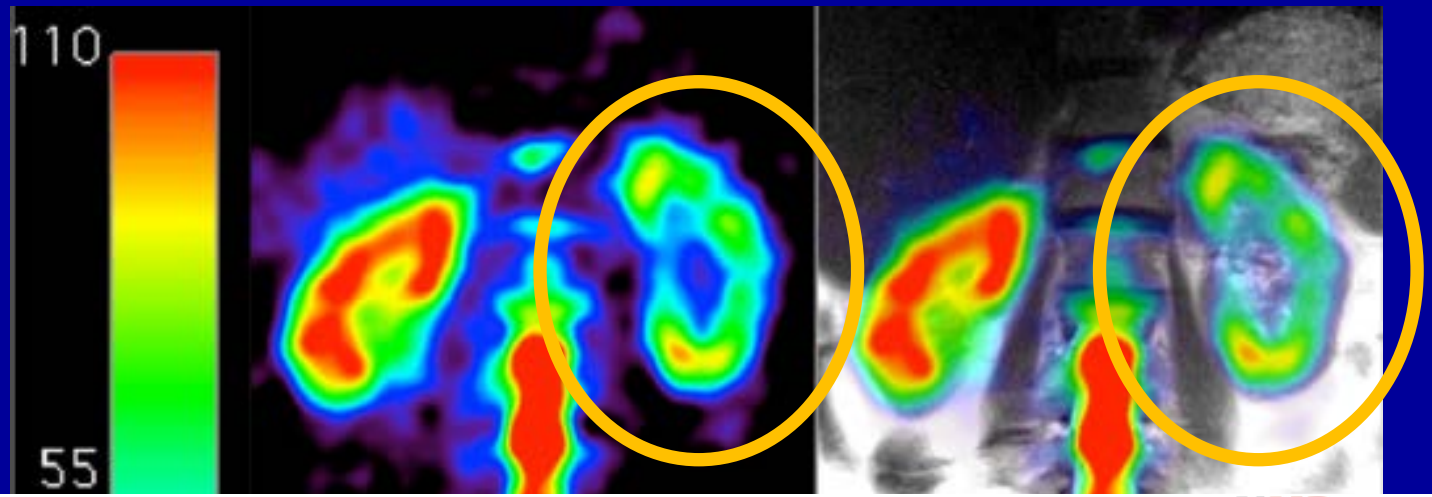


Platt et al. ISMRM UHF workshop 2016

Renal ^{23}Na MRI
After Radiotherapy/ After Kidney Transplantation

Cortico-medullary Na^+ gradient & Na^+ concentration:

- decreased after kidney transplantation[1]
- decreased after radiotherapy[2]



Special issue review article

NMR IN BIOMEDICINE

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(wileyonlinelibrary.com) DOI: 10.1002/nbm.3274

Quantitative sodium MRI of kidney

Frank G. Zöllner[a]*, Simon Konstandin[a,b], Jonathan Lommen[a], Johannes Budjan[c], Stefan O. Schoenberg[c], Lothar R. Schad[a] and Stefan Haneder[c,d]

1) Moon et al. Eur Radiol 2014

2) Zöllner et al. NMR Biomed 2016

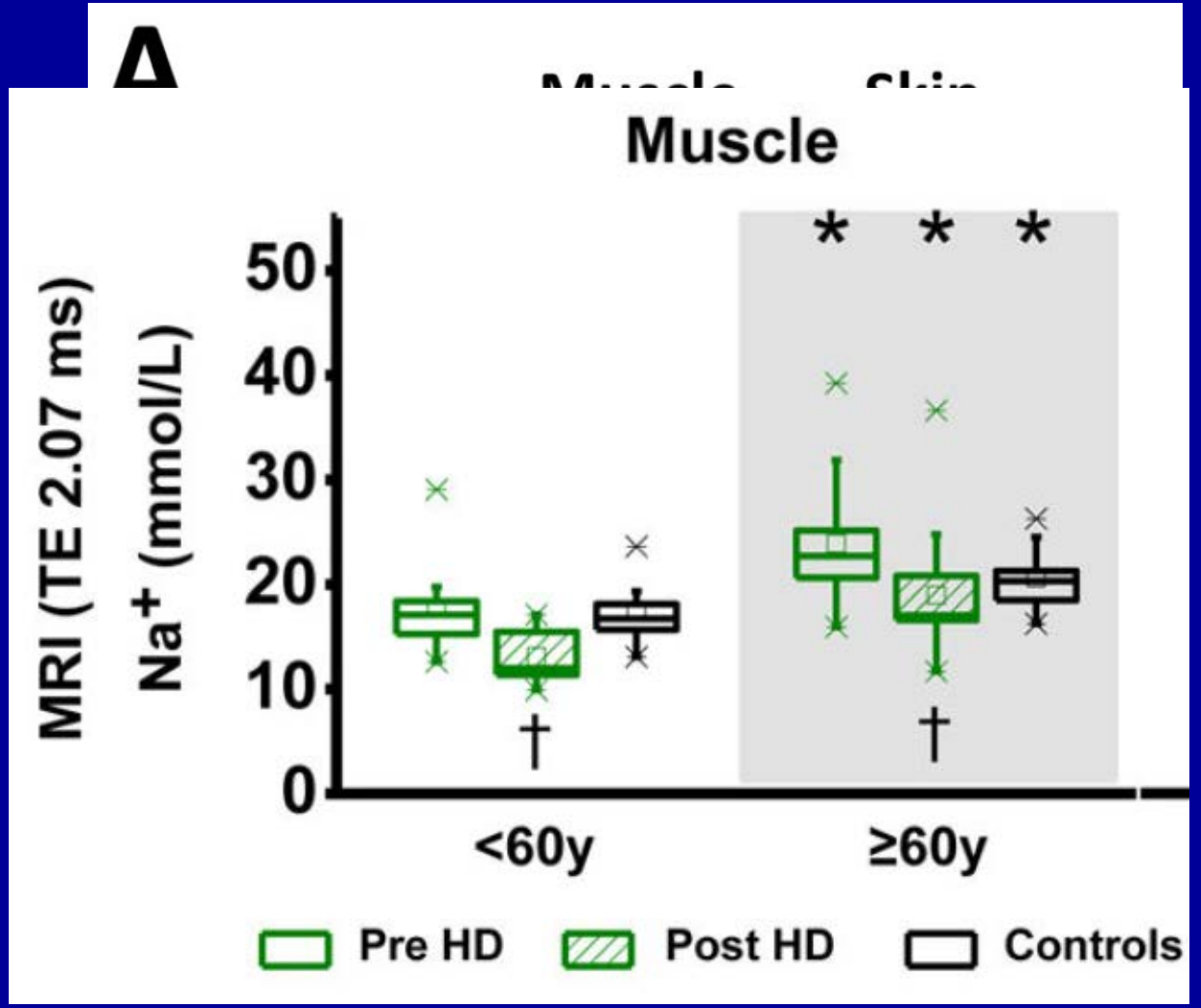
^{23}Na MRI
Renal Imaging/ Applications in Renal Diseases

- Direct Renal Imaging

- Effects of Renal Diseases on tissue Na^+ homeostasis

Tissue Na^+ (Calf Muscle)
Pre and Post Hemodialyis

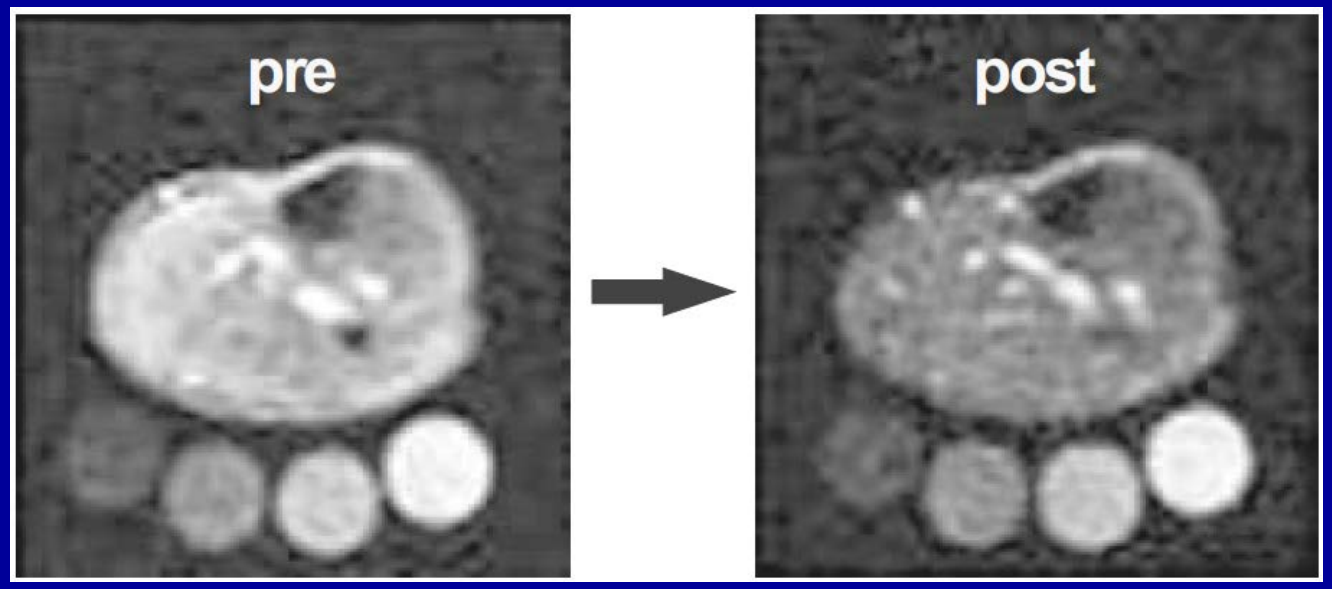
- HD treatment reduced tissue Na^+
- Post HD Na^+ (< 60 years)
  lower than Na^+ in controls

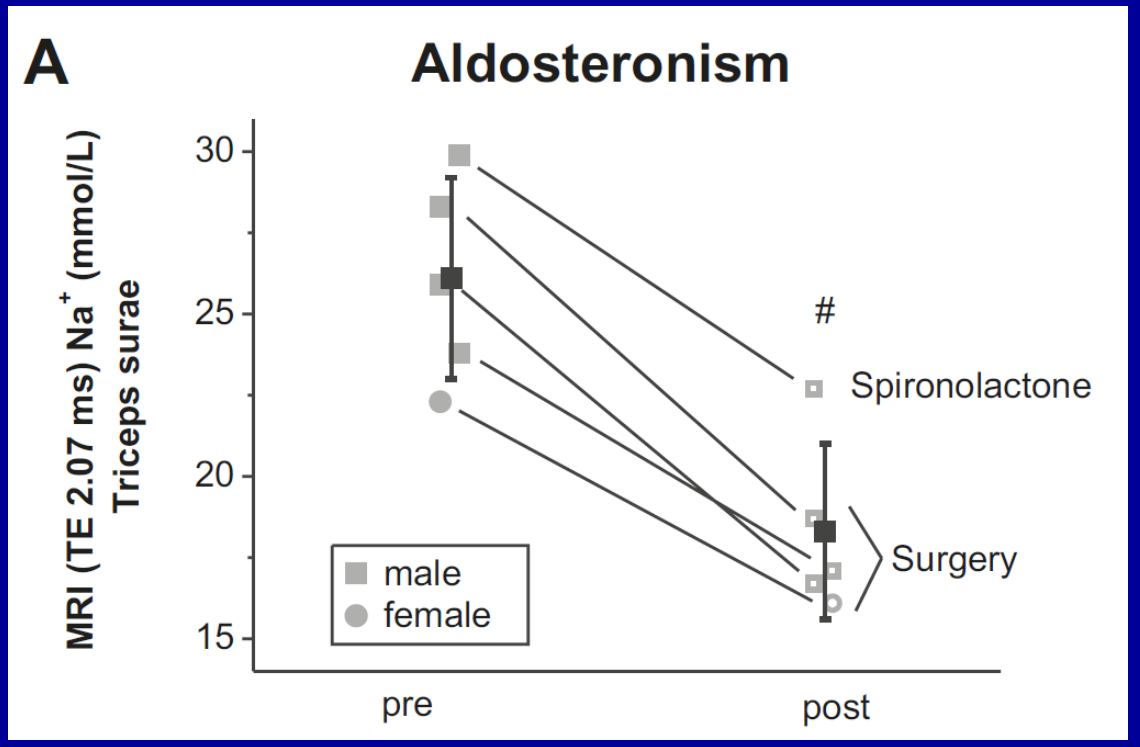


Dahlmann et al. Kidney Int. 2015

Conn‘s Syndrom

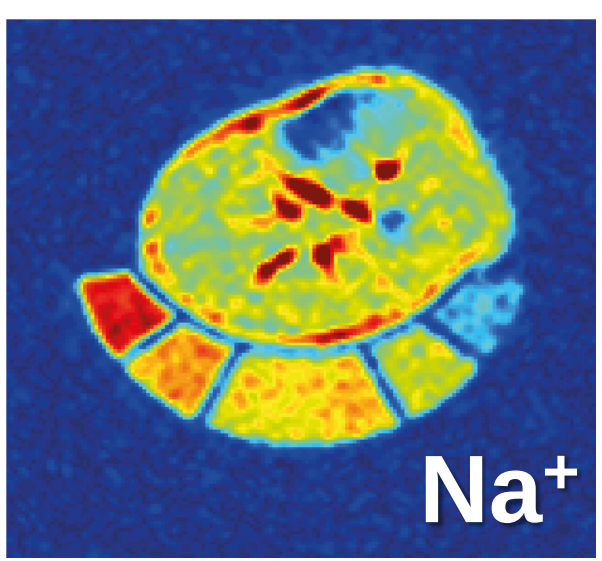
- adrenal glands: excess production of the hormone aldosterone
- increased Na^+ reabsorption and K^+ secretion

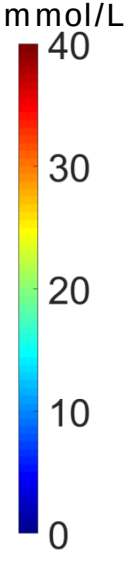


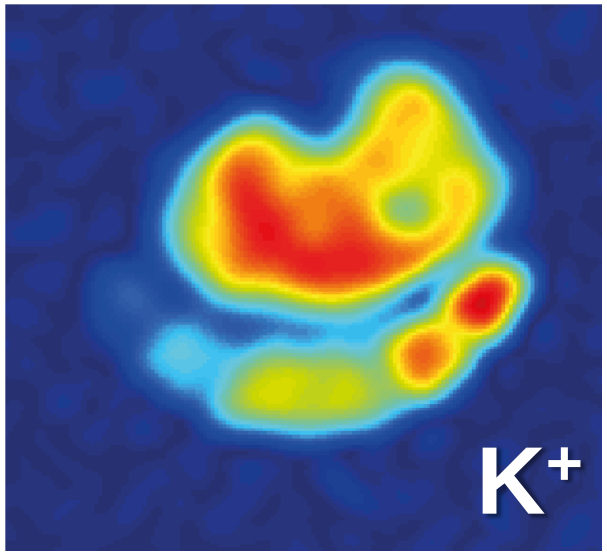


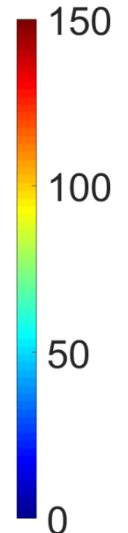
Kopp et al. Hypertension 2011

Combined ^{23}Na/ ^{39}K MRI









3x3x20 mm^3
T_{aq}= 7 min 56 s

10x10x40 mm^3
T_{aq}= 10 min 40s

Conclusion

^{23}Na MRI

- Requires dedicated hard- and software
- Provides interesting insights into tissue ion homeostasis
- Valuable research tool/ potentially future clinical tool

^{39}K MRI

- Research Tool at UHF (≥ 7 Tesla)