

NON-INVASIVE MRI METHODS FOR ASSESSING RENAL FUNCTION-²³Na MRI AND UREA CEST

ROBERT LENKINSKI, PHD

Department of Radiology and
Advanced Imaging Research
Center, UT Southwestern
Medical Center, Dallas, TX,
United States



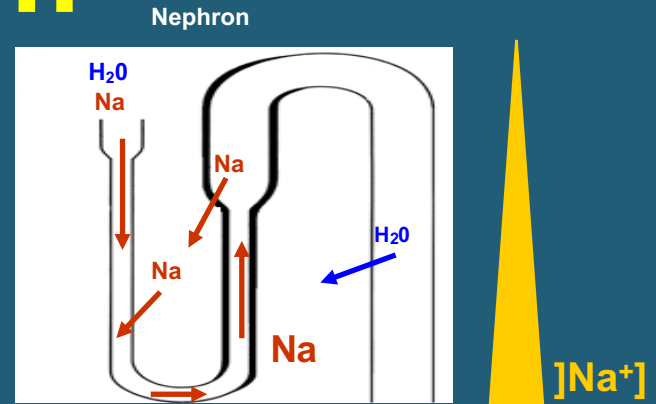
Sodium MRI of the Human Kidney at 3 Tesla

Nimrod Maril,¹ Yael Rosen,¹ Glenn H. Reynolds,³ Alex Ivanishev,¹ Long Ngo,² and Robert E. Lenkinski^{1*}

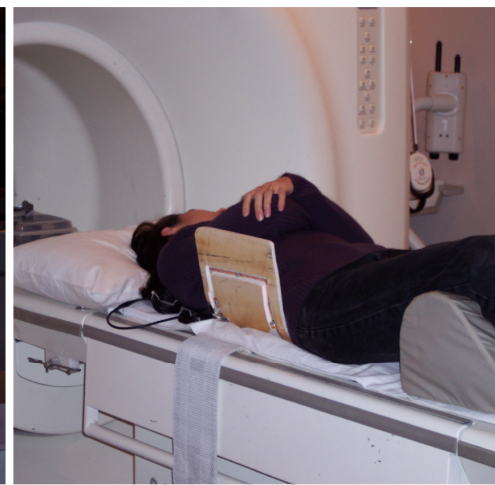
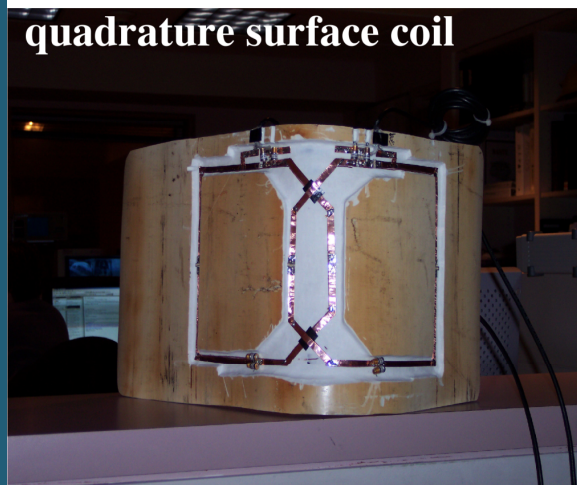
Renal Sodium Concentration

Renal physiology

The kidney concentrates sodium in the medulla as part of the fluid homeostasis regulation mechanism.



Na-23 Imaging of the Kidney at 3T



Need Multinuclear accessory, RF coil, pulse sequence, Image reconstruction

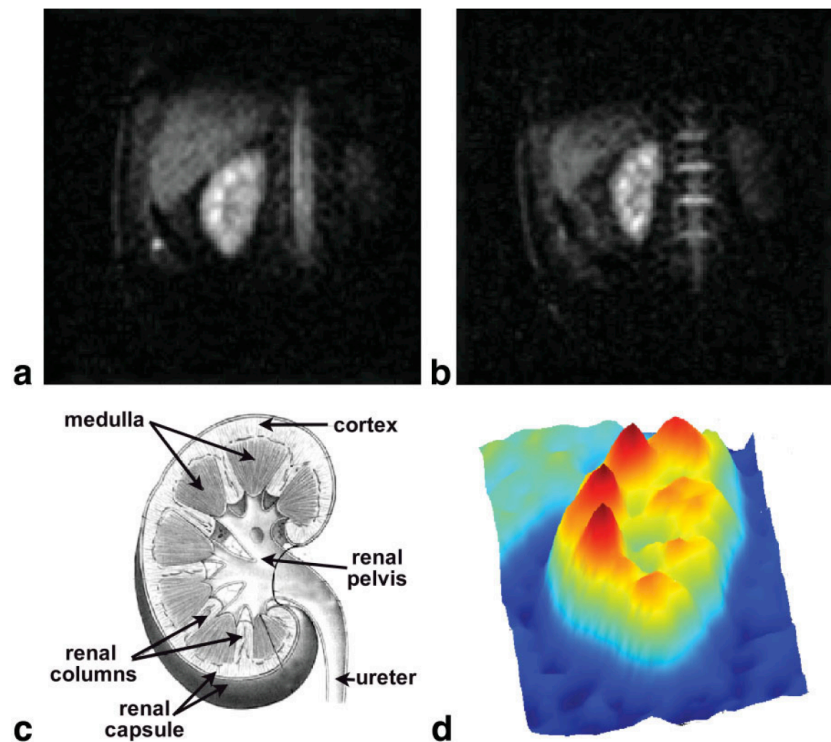


FIG. 2. Coronal projection of a 3D ^{23}Na image of the human abdomen acquired at 3T in 25-min (a) and 12-min (b) scanning times. Both images demonstrate the distribution of the sodium signal in the kidney and the surrounding environment. A comparison between a scheme of the human kidney (c) and a surface function of the signal intensity in a (d) reveals an increase in sodium concentration along the corticomedullary axes in accordance with the multipapilla structure of the human kidney. The images were acquired by a 3D gradient-echo sequence tailored for sodium imaging as described in Materials and Methods, using an in-house-built quadrature surface coil with $\text{TR}/\text{TE} = 30/1.8$ ms, $\text{FOV} = 38 \times 38 \times 24$ cm, and $\text{matrix} = 128 \times 128 \times 16$.

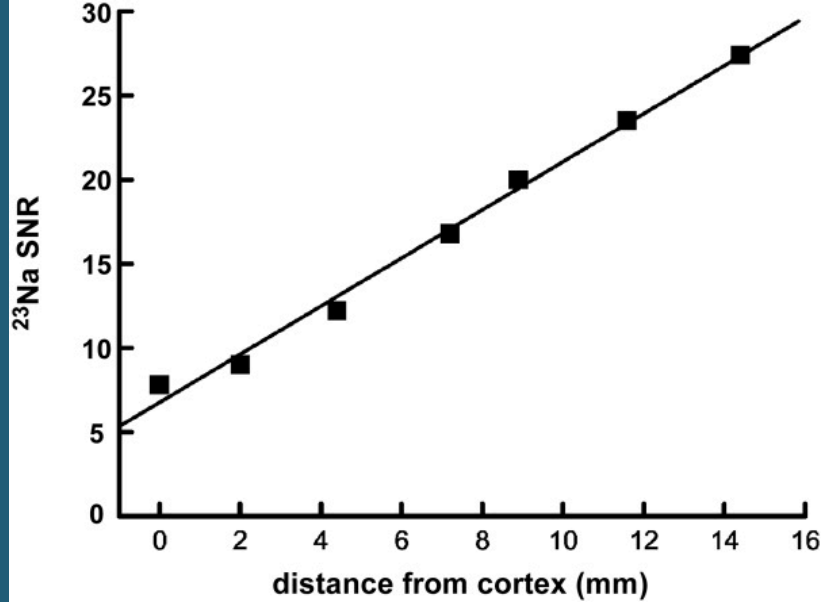
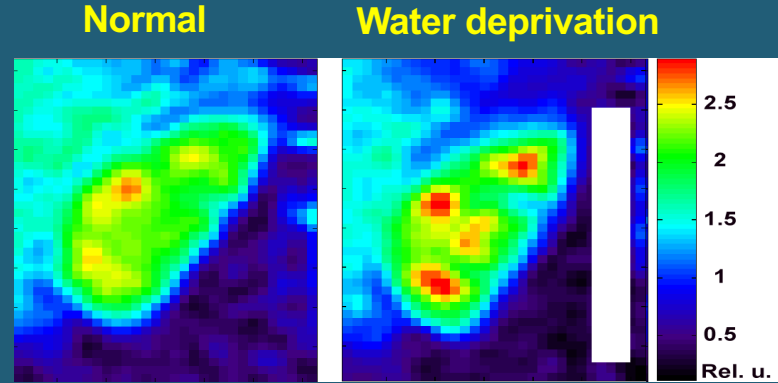


FIG. 3. Plot of the sodium SNR along a typical corticomedullary axis of a human kidney under normal conditions, measured from a sodium image acquired as described in Materials and Methods. After the coil sensitivity was corrected for, sodium signal intensities were measured at pixel resolution and referenced to the noise level. The increase of sodium SNR along the corticomedullary axis was linear ($R = 0.96 \pm 0.01$).

Normal Conditions VS. Water Deprivation

Sodium gradient increase at water-deprivation, as expected from the normal physiology of water preservation.



	Normal cond.	Water-deprivation	P-value*
ROI Analysis			
Medulla/Cortex Ratio	2.4 ± 0.1	2.7 ± 0.1	$P < 0.02$
Pixel-by-pixel Analysis			
Linear Slope (Rel.u./mm)	1.6 ± 0.2	2.0 ± 0.2	$P < 0.05$

* Linear mixed-effects model

Sodium MRI of a Human Transplanted Kidney¹

Yael Rosen, MD, Robert E. Lenkinski, PhD

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SODIUM MRI OF A TRANSPLANTED KIDNEY

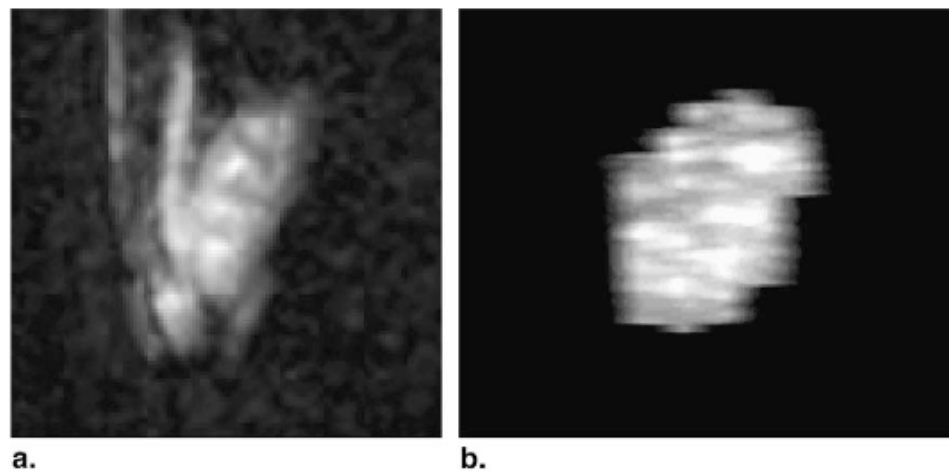


Figure 1. (a) A sagittal sodium reconstruction of two combined central slices of the three-dimensional ^{23}Na image acquired at 3T in 25 minutes. The transplanted kidney is clearly observed against the abdominal wall, showing the high-intensity medullary areas in the renal parenchyma. Data were acquired using a sodium surface coil and applying a three-dimensional gradient echo sequence tailored for sodium imaging with repetition time/echo time = 30/1.8 ms (partial Fourier echo), field of view = $38 \times 38 \times 24$ cm, matrix = $128 \times 128 \times 16$. (b) A coronal reconstruction of the cropped three-dimensional renal parenchyma, summed into a single coronal slice (using the inherent image processing tools of the scanner). This view facilitates the three-dimensional spatial localization of the main medullary areas.

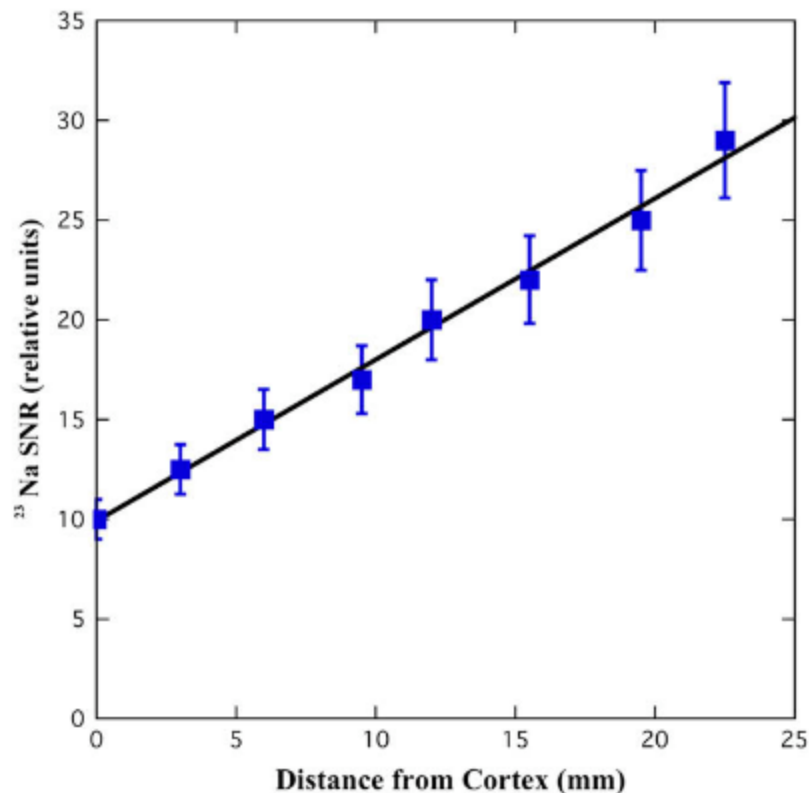
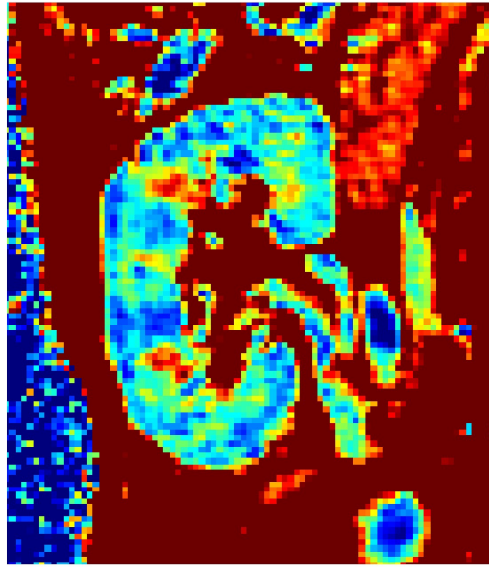


Figure 2. A plot of the sodium signal-to-noise ratio (SNR) along one of the corticomedullary axes, obtained from a sagittal sodium image acquired as described in the Methods section. The observed increase in sodium SNR along the corticomedullary axis was linear (in this example $r^2 > 0.99$). The error bars are based on the uncertainties present from the SNR measured at each point.

R2* map



^{23}Na image

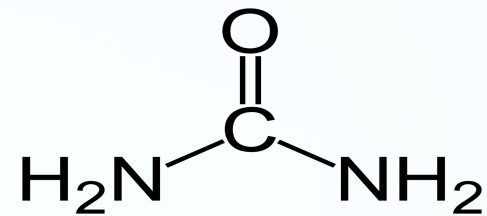


The spatially registered R2* map shown on the left and the Na-23 image shown on the right for a patient with a transplanted kidney showing CRF.

Endogenous Urea CEST MRI (urCEST): pH and urea gradient mapping in human kidney

Elena Vinogradov, PhD
Radiology

Why Urea?

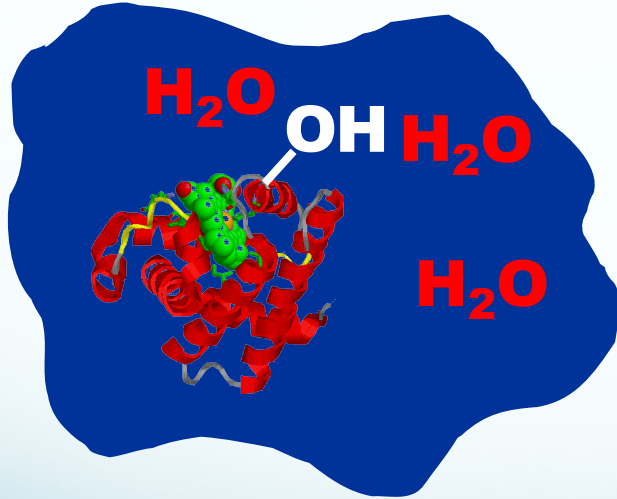


$\Delta_{\text{CS}} = 1 \text{ ppm}$

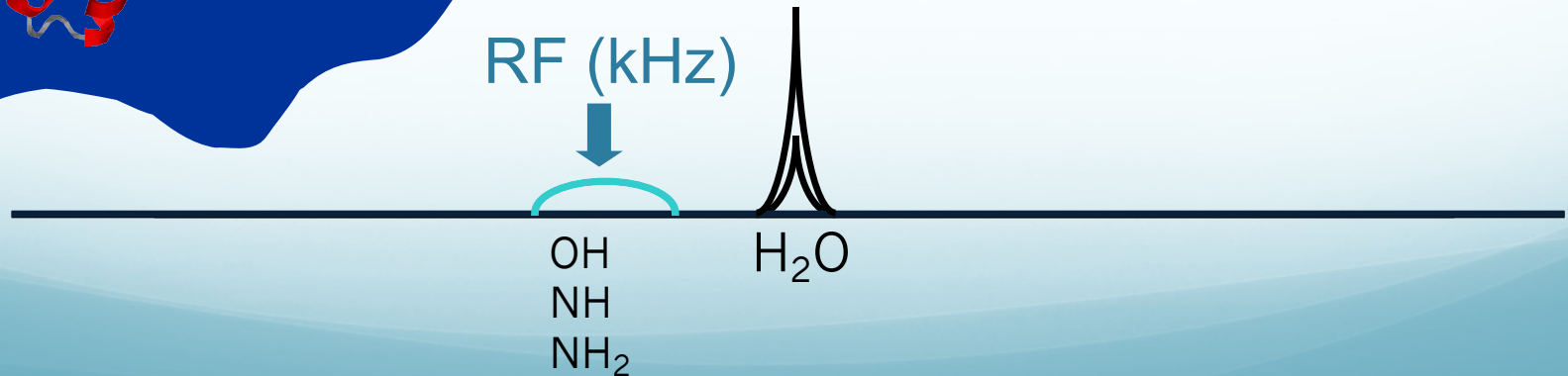
- Normal kidneys have well-defined cortico-medullar gradients of urea concentration and pH
- The gradient is spatially disturbed in many diseases.
- Quantitative urea mapping may be useful in:
 - Follow-up of Chronic Kidney Disease (CKD)
 - Follow up of a Shock Wave Lithotripsy (ESWL)
 - Renal cancer surgery planning
 - Follow up of a transplant allograft

MRI World: Chemical Exchange Saturation Transfer

“A new class of contrast agents for MRI based on proton
Chemical Exchange Dependent Saturation Transfer (CEST)”

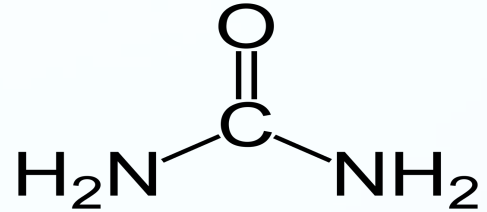


Wolf, et.al. JMR 86 164(1990)
Guivel-Scharen, et.al.JMR 133 36(1998)
Ward, et.al.JMR 143 79(2000)



MRI: Why Urea ?

- Endogenous molecule
- Strong CEST effect
- urCEST is dependent on pH
- First CEST reported in-vivo
[Dagher, et.al., JMRI, 12:745 (2000)]

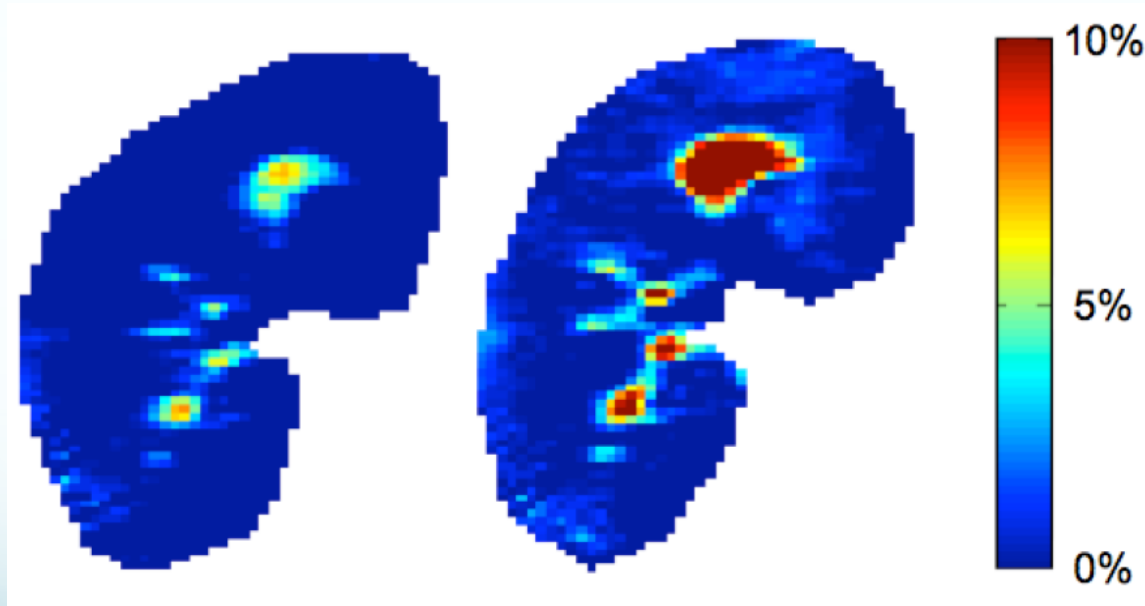


$$\Delta_{cs} = 1 \text{ ppm}$$

Results: In-Vivo modulation

“dehydrated”

“hydrated”



Healthy male volunteer

“Dehydrated”: no fluid and food intake for over 8 hrs

“Hydrated”: regular fluid and food intake

Summary

We have described two non-invasive methods for the direct assessment of renal function; Na-23 MRI and Urea CEST.

Na-23 requires specialized hardware, pulse sequence, and Image Reconstruction.

CEST can be performed on 3T clinical scanners with a pulse sequence and custom image processing and can provide both information about urea gradients and pH.

Urine in the bladder can serve as an internal standard.