

Quantitative and Qualitative Renal Sodium-Imaging at 3T

S. Haneder¹, S. Konstandin², F. G. Zöllner², A. M. Nagel³, L. R. Schad², S. O. Schönberg¹, and H. J. Michaely¹

¹University Medical Center Mannheim, Institute of Clinical Radiology and Nuclear Medicine, Mannheim, Baden-Württemberg, Germany, ²Heidelberg University, Computer Assisted Clinical Medicine, Mannheim, Baden-Württemberg, Germany, ³German Cancer Research Center, Department of Medical Physics in Radiology, Heidelberg, Baden-Württemberg, Germany

Introduction:

The function of the human kidney is correlated to the renal cortico-medullary sodium concentration gradient. In the last few years ²³Na magnetic resonance imaging was introduced for assessing the sodium concentration in renal tissue under different physiological conditions [1]. The aim of this prospective study is the in-vivo assessment of the cortico-medullary concentration of sodium in the human kidney before and after water load by magnetic resonance imaging at 3T.

Method and Materials:

All measurements were performed on a 3 Tesla clinical whole-body MR scanner (Magnetom TimTrio 32x102, Siemens Healthcare Sector). For signal reception a dedicated sodium-tuned cardiac coil with 8 coil elements (Rapid Biomedical) was used. It consists of two identical halves with a transmit loop and four receive-only channels each. The coil was tightly fixed around the volunteers and covered a coronar field-of-view of 320 x 320 mm². Beside both kidneys, standardized 0.6% and 0.9% NaCl-dilutions including 2% agarose were covered in the field-of-view serving as calibration phantoms. Based on the comparison of these phantoms, an analog increase of the sodium signal intensities compared to the sodium concentrations was estimated. For adjusting the inhomogeneity of the coil a priori, a homogeneous sodium phantom was measured as reference. According to this reference, all images of the volunteers were corrected. For the sodium concentration map, a density adapted 3D radial trajectory was used for acquisition [2] with the following parameters: TR = 120 ms, TE = 0.55 ms, flip angle = 85°, FOV = 320 x 320 mm², readout length per spoke = 20 ms, projections = 8000 resulting in a total scan time of 16 min. The isotropic spatial resolution was 5 mm.

After institutional review board approval and informed consent, 9 healthy volunteers (24-33 years, mean age: 29 years; 6 male, 3 female) were included. Imaging was performed before and after water load with 1 liter water with an intermission of half an hour. The healthy volunteers were asked to abstain from water 6h before first imaging. The cortico-medullary sodium gradient was assessed by pixel-by-pixel analysis from the definable cortex to the inner medulla of both kidneys as signal intensity. Data were acquired for all detectible renal medullas in each slice. The cortico-medullary signal intensities were correlated with the signal intensity of regions-of-interest placed in the external calibration phantom and therefore quantified as sodium concentration in mmol/L. All statistical data are given as means and standard deviations.

Results:

All data were successfully acquired. The signal intensity increased linear before water load from 36.8±1.2 (cortex) to 66.3±5.0 (medulla). A quantitative sodium concentration increase from 57.6±3.9 mmol/L (cortex) to 103.9±2.8 mmol/L (medulla) was computed. After water load the signal intensity increased from 33.7±2.1 (cortex) to 54.3±2.0 (medulla) and respectively the sodium concentration from 48.6±2.9 mmol/L to 80.6±3.5 mmol/L. This corresponds to a decrease of the sodium concentration after water load of 15.5% (cortex) and 22.4% (medulla).

Conclusion:

This study suggests that sodium imaging on a clinical 3T scanner might be an appropriate, noninvasive method for physiological imaging of the human kidney. The current sodium imaging technique is sufficient for the quantification of the renal, cortico-medullary sodium concentration and its change in different physiological conditions.

References:

- [1] Maril N, Margalit R, Mispelter J, Degani H. Sodium Magnetic Resonance Imaging of Diuresis: Spatial and Kinetic Response. *Magn Reson Med* 53:545-552 (2005)
- [2] Nagel AM, Laun FB, Weber MA, Matthies C, Semmler W, Schad LR. Sodium MRI using a density-adapted 3D radial acquisition technique. *Magn Reson Med* doi:10.1002/mrm.22157 (2009)

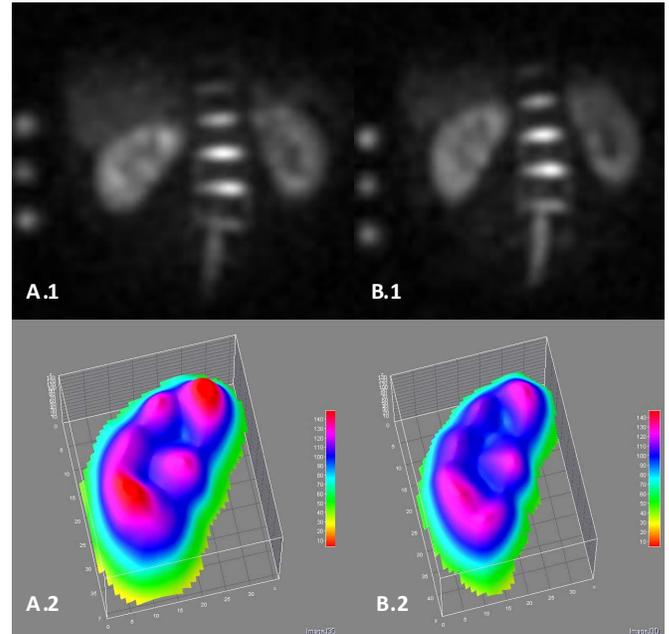


Figure 1. Sodium images before (A.1) and after (B.1) water load. A.2 and B.2 demonstrate the distribution of the sodium signal intensity before and after water load.

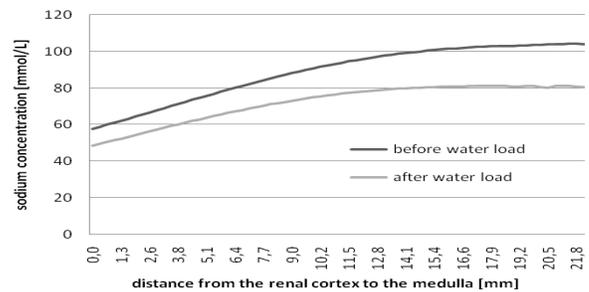


Figure 2. This graph illustrates the sodium concentration as a function of the intrarenal location from cortex towards the medulla.