SODIUM T₂* MAPPING OF THE HUMAN KIDNEYS IN VIVO AT 7 TESLA

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TARGET AUDIENCE: Abdominal radiologists, physicists interested in sodium T₂* mapping and in developing sequences for fast relaxing tissues.

PURPOSE: In vivo sodium (²³Na) MRI of the kidneys is not only challenging because of its intrinsic low concentration, but also due to its very short biexponential transversal relaxation, consisting of a fast (≈60% of signal) and slow component (≈40% of signal). To date, ²³Na T₂* relaxation times in the kidneys have been measured solely in animals.1,2 However, for absolute quantification of ²³Na content and for sequence optimization, it is essential to know the T₂* values in the human kidneys. Recent technical and methodological developments for 7T systems improved ²³Na MRI and enabled studies that were not possible previously. Thus the aim of this study was to measure the T₂* relaxation times of the human kidney in-vivo at 7.0T for the first time.

METHODS: Eight healthy volunteers (4 women, 4 men) with a mean age of 29.4±3.6 (mean±standard deviation) years (range: 24.5-33.5 years) and a mean body-mass-index of 21.7±2.6 kg/m² (range: 19.5-27.5 kg/m²) were included in this prospective study. All volunteers were asked to avoid drinking of water within 60 minutes before the examination. There were no other restrictions of food and water intake. The local ethics commission approved this study and written informed consent was obtained from all volunteers before measurements. All measurements were performed on a 7T whole body system (Magnetom, Siemens Healthcare, Erlangen, Germany) with a six-channel ²³Na-only spine-array coil (Quality Electrodynamics, Mayfield Village, Ohio, USA). After a series of localizers, a multi-echo 3D gradient-echo sequence with a variable echo time scheme (vTE-GRE) was applied to map T₂* relaxation times in the kidneys. The echo times were sequentially shifted; during first TR all odd TEs and during second TR all even TEs were recorded. Measurement parameters for vTE-GRE were as follow: resolution= 4x4x15 mm³; 12 slices; 10 echo times with TE=2.64, 4.93, 13.76, 19.18, 24.59, 30.01, 40.00, 45.42, 55.00, 60.42 ms; TR= 75 ms; BW=60 Hz/pixel; 24 averages; measurement time=46:50 min. The T₂* maps (Fig 1B) were calculated by fitting the ²³Na signal decay mono-exponentially on a pixel-by-pixel basis using a least squares fitting routine with three parameters written in IDL (RSI, Boulder, CO, USA) (Fig 2). To assess the fitting precision, a corresponding measure of goodness-of-fit (R²) map (Fig 1C) was calculated for each T₂* map in IDL. Two coronal T₂* maps representing the center part of the kidneys were evaluated in each volunteer using OsiriX (OsiriX, Geneva, Switzerland), totaling to 32 measurements. The vTE-GRE images with the shortest TE (2.64 ms) (Fig 1A) were used to manually draw region-of-interest (ROI) around the visible renal cortex and the medulla. The partially seen calyceal systems of the kidneys were spared. The ROIs were subsequently copied from the vTE-GRE image to T₂* and R² maps and the mean values and corresponding standard deviations were obtained. All statistical analyses were performed using MedCalc (MedCalc, Mariakerke, Belgium). A Kolmogorov-Smirnov test verified normal distribution of the data (p=0.659). A paired t-test was used to compare the T₂* values of the renal cortex and the medulla.

RESULTS: The mean ²³Na T₂* relaxation times of all volunteers were 17.9±1.2 ms (range: 16.5-19.1) in the renal cortex and 20.4±1.5 ms (range: 18.7-22.4) in the medulla. The mean R² were 0.987±0.008 in the renal cortex and 0.993±0.005 in the renal medulla A paired t-test revealed significantly lower T₂* values in the renal cortex when compared to the medulla (p<0.001).

DISCUSSION: To the best of our knowledge, the literature reports only animal T₂* data from kidneys, and therefore this is the first report on in vivo human T₂* relaxation times in the kidneys. Due to the quite long first TE (2.64 ms), the contribution of the short component of the biexponential decay was minimal and our T₂* values represent mainly long T₂* component. Slightly different T₂* relaxation times were published from animal models. Maril et al. reported a short (2.2 ms) and a long T₂* component (20.4 ms) for intact rat kidneys at 4.7T.1 For surgically exposed rabbit kidneys at 4.7T, Wolff et al. showed a long T₂* component of 20.1±2.0 ms in the cortex and 25.3±1.2 ms in the medulla.2 Neuberger et al. calculated a long T₂* of 29.2±3.8 ms for the cortex, 36.1±2.8 ms for the medulla, and a fast T₂* component of 0.8±0.6 ms for the cortex and 1.0±0.6 ms for medulla in the mice kidneys at 17.6T.3 Our T₂* results are in good agreement with the long T₂* components published by Maril et al.1 and Wolff et al.2 Moreover, similar to the results from animal studies, we observed shorter T₂* values in the renal cortex compared to the medulla.

CONCLUSION: The high SNR provided by 7T and multi-echo vTE-GRE sequence allowed the in vivo measurements of ²³Na T₂* relaxation times in human kidneys for the first time. This data may provide the basis for absolute quantification of ²³Na content in human kidneys.