Introduction and Evaluation of Different Approaches for the (Semi-)quantitative Assessment of Renal Sodium Content with 23Na MR Imaging

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Introduction:

In the past few years, the feasibility of *in-vivo* ^{23}Na MR imaging of the human kidneys has been demonstrated in both animal and human studies under various physiological conditions [1,2]. The function of the human kidney is correlated to the renal cortico-medullary sodium concentration gradient, known to increase in the direction of the renal medulla. Several approaches for the (semi-)quantitative assessment of the renal sodium content have been introduced based on region-of-interest (ROI) analysis. The mainly used approach is to measure the ^{23}Na signal pixel-by-pixel along a linear ROI from the cortex to the medulla (cortico-medullary ^{23}Na gradient). With the use of external reference phantoms this ^{23}Na signal gradient can be mathematically quantified in absolute concentrations [1]. This quantitative measurement is technically sophisticated and prone to artifacts. To simplify the determination of the renal ^{23}Na content, two different approaches were evaluated in this study.

One technical more simple approach is to evaluate the cortico-medullary ^{23}Na signal gradient (as used for the quantification) but to abstain from the external references and to use instead an internal one – the cerebrospinal fluid (CSF - ^{23}Na$_{CSF}$). In the second approach the numbers of evaluated slices for quantification of the cortico-medullary ^{23}Na gradient were reduced. Due to the spatial resolution the kidneys were visible in 6-8 slices (*Figure 1*). In this second approach different scenarios were calculated with only 2 to 4 evaluated slices.

Method and Materials:

After institutional review board approval and informed consent, 12 healthy volunteers (8m, 4f; mean age – 28.5y) were imaged on a 3.0 Tesla clinical whole-body MR scanner (MAGNETOM TimTrio 32x102, Siemens Healthcare Sector) before an after a water load of 1L. For ^{23}Na imaging a commercially available, dedicated sodium-tuned cardiac coil with 8 coil elements (Rapid Biomedical) was used. This coil consists of two identical halves with a transmit loop and four receive-only channels each, covering in total a coronal field-of-view of 320 x 320 mm^2. Beside both kidneys, standardized 0.6% NaCl-dilutions including 2% agarose were covered in the field-of-view serving as external reference phantoms. For the sodium concentration map, a density adapted 3D radial trajectory was used for acquisition with the following parameters: TR = 120ms, TE = 0.55ms, flip angle = 85°, FOV = 320 x 320mm^2, readout length per spoke = 20ms, projections = 8000 resulting in a total scan time of 16min. The isotropic spatial resolution was 5mm. Cortico-medullary ^{23}Na-concentration gradients were quantified for the linear increase (10mm from the cortex to the medulla) in mmol/l/mm before and after the water load. This measure was utilized as the gold standard against which the accuracy of two different technically more simple approaches to assess sodium content were compared. For the first approach (^{23}Na$_{CSF}$), a ROI was placed in the visible CSF in each slice and the mean calculated. The cortico-medullary ^{23}Na signal was divided through the mean CSF before and after the water load.

For the second approach (reducing the numbers of evaluated slices) four different scenarios were calculated. Scenario 1 utilized the two central-most images within the kidney (i.e. images 3 and 4). Scenario 2 included these two images and the immediate ventrally adjacent image (i.e. images 2-4). Scenario 3 incorporated the two central-most images and the immediate dorsally adjacent image (i.e. images 3-5), and scenario 4 included the 4 center-most images (i.e. images 2-5). Paired-t-test were used to find significant differences between the gold standard (quantification) and the two new approaches.
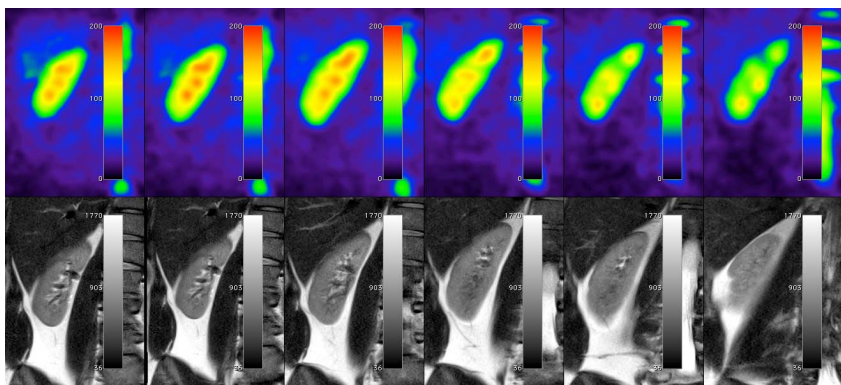

Figure 1. *This panel shows 6 representative slices of the right kidney of one healthy volunteer (upper row - ^{23}Na concentration maps; lower row – corresponding T2w images). For the second approach the evaluated numbers of slices were reduced.*

Results:

All data were successfully acquired. ^{23}Na$_{CSF}$ values decreased at every point along the corticomedullary gradient following water load. The magnitude (26.7-29.9%) of the CSF-based quantification of decrease was not statistically significantly different from those seen with the gold standard of quantitative measurements ($0.45 \leq p \leq 0.83$). A slice reduction scheme whereby only the centrally located two slices of the kidney and an additional more ventral slice were utilized exhibited similar changes in sodium gradients following water load as did the gold standard approach utilizing all slices ($p=0.54$).

Conclusion:

The two approaches introduced for simplifying assessments of renal ^{23}Na content all reproduce decreases in ^{23}Na content observed with an oral water load utilizing a more technically cumbersome quantitative measurement. The results of the two introduced approaches are not statistically significantly different in magnitude compared to the quantitative gold standard. Both approaches seem to be a feasible and faster alternative compared to the absolute quantification of the cortico-medullary ^{23}Na gradient, especially for a potential implementation in the clinical routine.

References:

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