Sub-millimeter ^{23}Na Imaging in Human Calf Skin at 7.0T

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Introduction: High-salt intake is said to cause hypertension, the "major" killer in our society. However, why and how-come, are not answered. Skin tissue was discovered as an important reservoir for sodium (Na) storage in hypertensive man and animals because of binding to glycosaminoglycans [1]. To gain better understanding about sodium storage in humans, ^{23}Na-MRI at 7.0 T is conceptually appealing as it opens the potential to measure [Na] at high resolutions non-invasively (typical spatial resolution (4 mm)^3) [2]. ^{23}Na-MRI of the skin is challenging because of the sub-millimeter resolution needed, low SNR and the fast biexponential ^{23}Na T_2^* decay. For this purpose, we propose a dedicated ^{23}Na coil to accomplish the first ^{23}Na-MRI images of the skin with a sub-millimeter in plane resolution.

Methods: Healthy volunteers were examined on a 7.0 T whole body system (Magnetom, Siemens Medical Solutions, Erlangen, Germany) using a home built ^{23}Na-surface-coil with two loops of (5 x 6) cm^2 (Fig.1). The two loops are capacitively decoupled. The small coil size and the low resonance frequency (78.5 MHz) do not require an RF screen. The coil was positioned inside the basic ^{1}H-birdcage-coil (Siemens) for reference anatomical images. A standard proton localizer was used for anatomical reference. ^{23}Na-MRI was performed using a gradient echo sequence (2D FLASH, FA / TE / TR = 34° / 5.27 ms / 8.2 ms, Pixel Bandwidth = 280 Hz, FOV = 115 mm, (0.9 x 0.9 x 30) mm^3 with 572 averages for a total acquisition time of 10 minutes. To characterize the performance of the surface coil, a B_1 map on a 100 mM NaCl phantom was acquired with the double angle method [4, 5] using the same sequence as above but with FA_1 / FA_2 / TR = 60° / 120° / 200 ms with 200 averages and an acquisition time of 170 minutes.

Results: **Fig. 1** shows the design of the ^{23}Na surface coil. In **Fig. 2** the flip angle (FA) map acquired on a phantom shows the high sensitivity of the coil near the surface; the FA decays to about the half at a distance of 1 cm from the surface. B_1 maps in vivo showed a similar profile, although SNR was very poor with only few averages. **Fig. 3** shows an anatomical proton image of the calf, superimposed with a colour coded ^{23}Na image.
Figs. 4 and **5** show the high resolution (0.9 x 0.9 x 30) mm^3 ^{23}Na MR image in human calf, demonstrating high ^{23}Na sodium content in the skin; the mean SNR in the skin is of about 20.

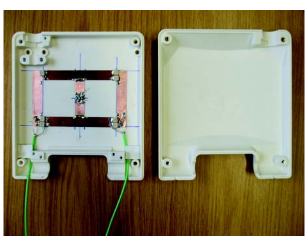

Fig. 1: Home built 2 channel capacitively decoupled 23Na surface loop (5 x 6 cm) coil, based on the design in [3].

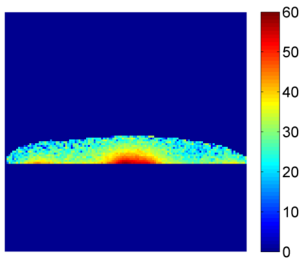

Fig. 2: Flip angle map of the ^{23}Na coil on a 100mM [Na] water phantom. The nominal FA (60°) is reached only at the centre, on the surface of the coil. FOV = 115mm

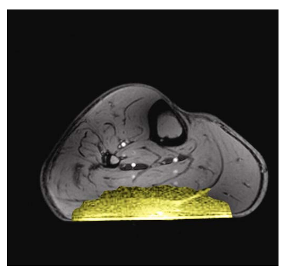

Fig. 3: Reference anatomical ^{1}H image of the calf, with over imposed ^{23}Na image (yellow coloured).

Fig. 4: High resolution ^{23}Na MRI image in human calf. The strong signal which arises from the skin has a SNR = 20. FOV = 115mm.

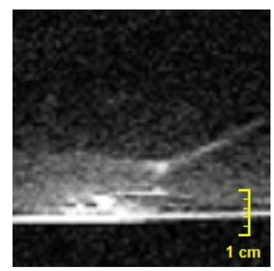

Fig. 5: Zoom of fig. 4, to highlight the sodium signal in the skin at submillimeter resolution.

Conclusion and discussion: In these preliminary experiments, the high sensitivity of the surface coil has enabled the acquisition of ^{23}Na MR images at a resolution inferior than 1mm in the thin layer of the skin, revealing for the first time its tremendous sodium content. As the B_1 map is mostly dependent on the coil and not significantly on the loading, it may be used in the future for ^{23}Na signal correction, which, together with T_1 and T_2* corrections, may lead to a ^{23}Na quantification. Pulse sequences other than GRE may be employed for a detection of the fast decaying component [6]. Within the region of sensitivity of the coil, the skin tissue shows a high signal within a thin layer of approximately 1mm between the coil surface and the nearly Na-free fat tissue. The findings indicate that Na is stored in a third space "in the skin" attached to proteoglycans. This idea is a radical turn from conventional Na homeostasis. Second, we can measure this distribution with ^{23}Na MRI. We document here, how a novel idea about salt balance can be investigated with ^{23}Na MRI.

References:
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