In vivo chlorine-35, sodium-23 and proton magnetic resonance imaging of the rat brain

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Introduction

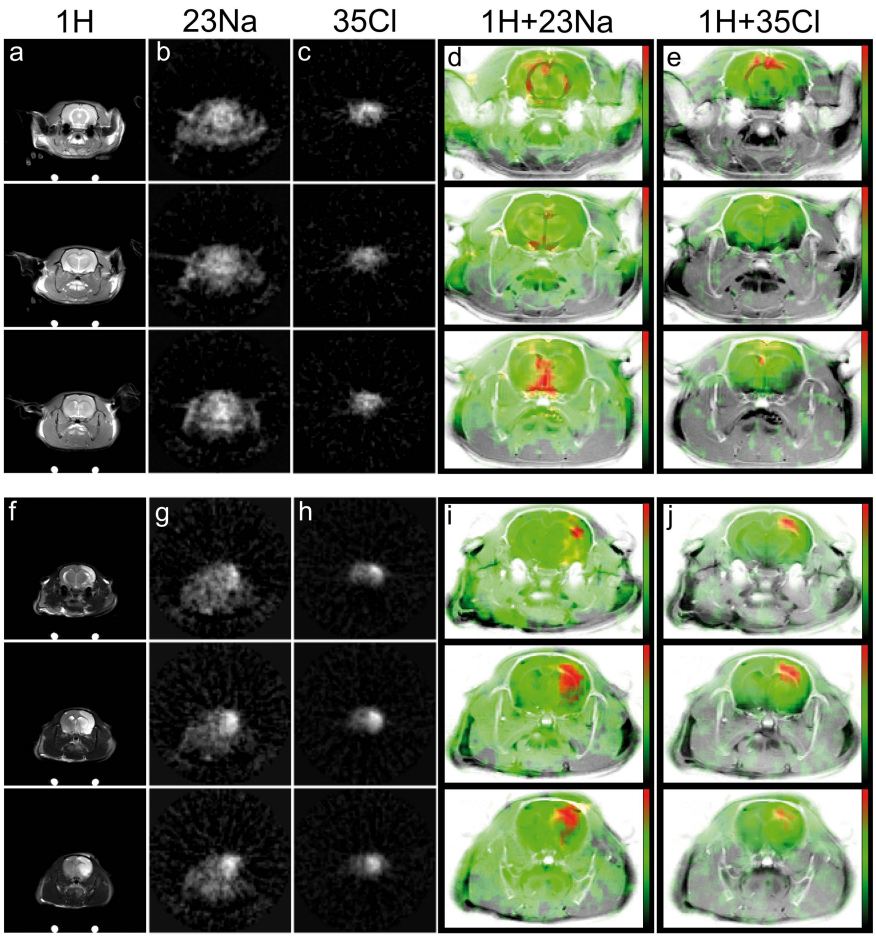
Chloride (Cl^-) is the most abundant *anion* in the mammal organism playing an important role in many cellular processes. For instance, plasma membrane Cl^- currents are important for the regulation of excitability in nerve and muscle. Moreover, Cl^- ions play a crucial role in controlling the ionic composition of the cytoplasm and the volume of cells [1]. In order to investigate the feasibility of combined *in vivo* ^{35}Cl, ^{23}Na and ^{1}H MRI we developed a rf coil setup to measure ^{35}Cl, ^{23}Na and ^{1}H signals in one scanning session without moving the subject or changing the setup.

Material and Methods

For the ^{1}H and ^{23}Na measurements we used a linear double tuned volume resonator with an inner diameter of 7 cm from Bruker (Ettlingen, Germany). Additionally, we placed a surface coil on the head of the animal that operated at the resonance frequency of ^{35}Cl at 9.4 T of 39.2 MHz. This coil was constructed from silver wire with 3 mm diameter. A single loop of 35 mm diameter was bent on a 35 mm plexiglass half cylinder to achieve an optimal filling factor for a rat head. The ^{35}Cl coil was built large enough to cover the whole brain for sure and is glued to the plexiglass half cylinder to which it was bent.

Proton imaging was performed using a multi slice multi echo (MSME) sequence with $TR = 2000$ ms, $TE_1 = 13$ ms and $TE_2 = 65$ ms (two images per slice). The field of view (FOV) was 64×64 mm^2 at a matrix of 256×256 with 9 coronal slices of 3 mm thickness and an inter-slice distance of 3.5 mm. The total measurement time (TA) was 6 min 24 sec.

The ^{23}Na and ^{35}Cl imaging was done using a slice selective ultra short echo time (UTE) pulse sequence with radial k-space acquisition [2]. For both nuclei 3 coronal slices with FOV = 64×64 mm^2, matrix of 64×64, slice thickness = 3 mm and an inter-slice distance of 3.5 mm were measured. The positions of the 3 slices were matched with the slice positions of the corresponding ^{1}H images by means of the scanner software Paravision® 5. The parameters for the ^{23}Na imaging were $TR = 40$ ms, $TE = 0.321$ ms, readout bandwidth = 25 kHz/FOV, number of averages = 225 and $TA = 30$ min 17 sec. For the ^{35}Cl imaging the following parameters were used: $TR = 40$ ms, $TE = 0.448$ ms, readout bandwidth = 25 kHz/FOV, number of averages = 455 and $TA = 1$ h 1 min.



Results and Discussion

Multinuclear MRI of ^{35}Cl, ^{23}Na and ^{1}H was applied on the head of a healthy rat and on a rat displaying a focal cerebral infarction in the right hemisphere of the brain. Columns a-e show the results of the *in vivo* MRI on a healthy rat whereas columns f-j show the results measured on a rat displaying a focal cerebral infraction. In the T_2 weighted ^{1}H images the area of infarction can be identified by the brighter areas in the right hemisphere of the brain due to ischemic swelling. Similar behaviour is observed in the ^{23}Na and ^{35}Cl images. Compared to the healthy tissue, a signal enhancement of a factor of 2.9 (^{23}Na) and of 2.2 (^{35}Cl) is observed in the area of infraction. The increase in signal is attributed to an increase in concentration of sodium and chloride ions. Note, the ^{35}Cl images were measured with a surface coil therefore mainly the brain of the rat is visible in the corresponding images (column c + h).

The coil setup and the measurement parameters of the ^{35}Cl and ^{23}Na MRI were a compromise in order to achieve almost the same image quality (SNR and resolution). Despite the fact that the signal intensity of ^{35}Cl is expected to be approx. 9.6 times lower than the signal intensity of ^{23}Na, the ^{35}Cl signal was sufficient to perform *in vivo* ^{35}Cl MRI with acceptable image quality in a measurement time of 1h. The total measurement time for the multinuclear MRI was 2h. ^{35}Cl MRI allows non-invasive *in vivo* studies on pathologies or physiological processes which result in a change of Cl^- concentrations. Since chloride and sodium ions are transported concurrently, combined *in vivo* ^{35}Cl, ^{23}Na and ^{1}H MRI may provide a new approach to study diseases like stroke, ischemia or cystic fibrosis.

References:

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