^{39}K MRI of Rat Brain at 21.1 Tesla

Nagel, A.M. (German Cancer Research Center-DKFZ, Medical Physics in Radiology); Levenson, C.; Morgan, T. (Florida State U., College of Medicine); Gor'kov, P.; Brey, W.; Schepkin, V.D. (NHMFL)

Introduction

Sodium (Na^+), chlorine (Cl^-) and potassium ions (K^+) play a vital role in many cellular processes such as excitation, inhibition and volume regulation of cells. Compared to ^{23}Na MRI, ^{35}Cl and ^{39}K MRI exhibit markedly reduced signal-to noise ratio (SNR), which makes the application of ultra-high magnetic field strengths ($B_0 \geq 7$ T) highly desirable. The feasibility of in vivo ^{23}Na and ^{35}Cl MRI at 21.1 Tesla has recently been demonstrated [1] and ^{35}Cl MRI of human brain and muscle has been performed at 7 Tesla [2]. ^{39}K MRI data was only available from 7 and 9.4 Tesla human MRI systems [3,4] and from a 9.4 Tesla small animal system [5]. Thus, the aim of this work was to evaluate the feasibility of in vivo ^{39}K MRI at 21.1T and to compare ^{23}Na and ^{39}K relaxation times at 21.1T.

Experimental

MRI experiments were conducted using a vertical widebore 21.1T magnet (NHMFL) and a Bruker Avance console (PV5.1 software). The NMR frequencies of ^{23}Na and ^{39}K were 237.5 MHz and 42.0 MHz, respectively. Relaxation time measurements of model solutions containing 154 mmoL/L NaCl or 154 mmol/L KCL and different agarose gel concentrations (0% to 5%) were performed at 7 and 21.1 T. For the 7T measurements a whole-body 7T MR system (Siemens, Healthcare, Germany) was used. A spin-echo and a global inversion recovery sequence were used to determine transverse (T_2) and longitudinal relaxation times (T_1), respectively. The short and long components of the transverse relaxation times (T_{2f} and T_{2l}) were fitted using a bi-exponential model.

Results and Discussion

Transverse and longitudinal relaxation times of model solution are longer at 21.1 T (Fig. 1). Longitudinal (T_1) relaxation times of the whole rat brain were 41.6 ± 0.4 ms and 14.1 ± 0.1 ms for ^{23}Na and ^{39}K, respectively. In vivo transverse relaxation times of ^{39}K are markedly shorter than those of ^{23}Na (T_{2f}(^{23}Na)=4.9±0.2ms; T_{2l}(^{23}Na)= 33.2±0.2ms; T_{2f}(^{39}K)=1.9±0.2ms; T_{2l}(^{39}K)=14.3±0.3ms). ^{39}K MRI of the healthy rat brain is feasible (Fig. 2).

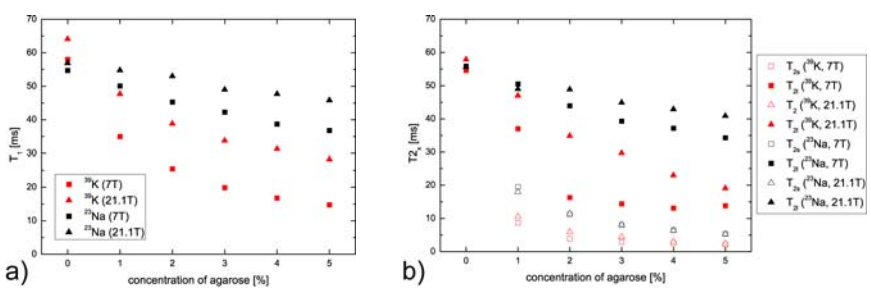

Fig.1 T1 (a) and T2 (b) relaxation times of ^{23}Na and ^{39}K. ^{39}K exhibits shorter relaxation times than ^{23}Na. Both, T_1 and T_2 relaxation times increase with magnetic field strength.

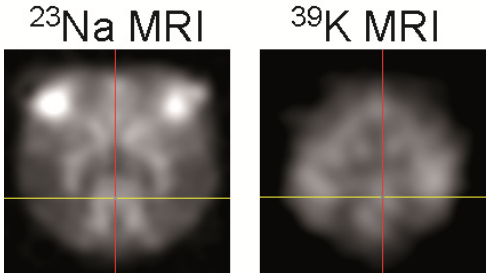

Fig.2 ^{23}Na and ^{39}K MRI of the healthy rat brain at 21.1T.

Conclusions

^{39}K MRI largely benefits from ultra-high magnetic fields and the acquired in vivo ^{39}K MR images of healthy rat brain show markedly improved image quality compared to previous work performed at 9.4 Tesla.

Acknowledgements

A portion of this work was performed at the National High Magnetic Field Laboratory, which is supported by National Science Foundation Cooperative Agreement No. DMR-0654118, the State of Florida, and the U.S. Department of Energy.

References

[1] Schepkin, V.D., *et al.*, Magn Reson Mater Phy, **27**, 63-70 (2014).
[2] Nagel, A.M., *et al.*, Radiology, **271**, 585-595 (2014).
[3] Umathum, R., *et al.*, Radiology, **269**, 569-576 (2013).
[4] Atkinson, I.C., *et al.*, Magn Reson Med, **71**, 1819-1825 (2013).
[5] Augath, M., *et al.,* J Magn Reson, **200**, 134-136 (2009).