In vivo MR Imaging of Chloride and Sodium in Rat Brain at 21.1 T

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Introduction

Ultra high magnetic fields expand our capability to perform MR imaging beyond commonly used proton imaging. The importance of low gamma nuclei (*low gyro-magnetic ratio*) for MRI remains practically unexplored, especially for *in vivo* applications. The main difficulty for MR imaging of such nuclei is the low intensity of their MR signals. Among such nuclei, sodium and chlorine nuclei have important advantages that they do not need to be added to living systems. The number of MRI scanners with high magnetic fields is nowadays increasing and sodium MRI is currently expanding its role as a unique tool for *in vivo* research and applications. Imaging of chloride is more challenging. Chloride has ~ 20 times less intensive MR signal than sodium plus the augmented interaction with variety of *in vivo* electric fields is leading to a more prominent bi-exponential relaxation of its MR signals.

Experimental

The MRI experiments were conducted using a 21.1T magnet (Tallahassee, FL), Bruker Avance III console (PV5.1 software) and gradient coil with *ID* = 64 mm (RR Inc.). The MR resonance frequencies for chlorine and sodium were 88.15 MHz and 237.5 MHz respectively. The 3D back-projection MRI pulse sequence was a modified version of the ultra-short echo time 2D pulse sequence provided by the Bruker PV 5.0 software.

Results and Discussion

The *in vivo* challenges of low sensitivity, short T2 relaxation times and the small size of the acquisition matrix were evaluated (Fig. 1 and Fig. 2). The concentration of chloride and sodium in normal rat brain were found to be 33.2 mM and 44.4 mM [1].

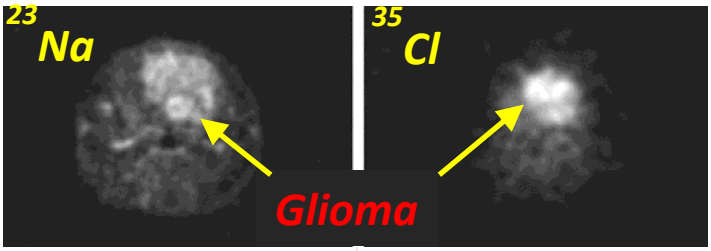

Fig. 1. *In vivo* sodium and chloride MRI of rat head. Chloride concentration is increased ~ 1.9 times in 9L glioma relative to a normal rat brain and a corresponding value for sodium is 1.6 times. The increased chloride concentration in glioma can be a precursor of tumor cell invasion.

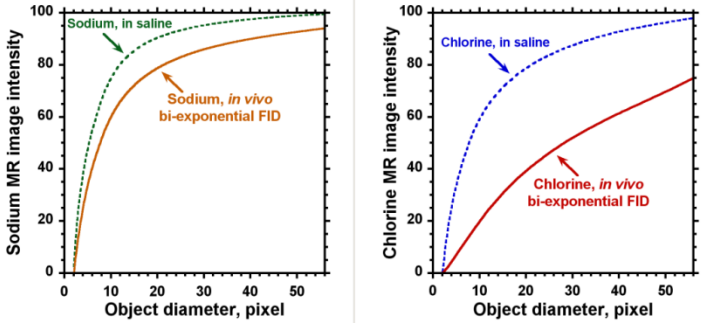

Fig. 2. MR image intensities of chloride and sodium signals depend on the object size due to a small acquisition matrix size and bi-exponential relaxation of MR signals. Both effects are important for quantification of MRI. Matlab modeling of such changes demonstrates these effects are much stronger for chloride than for sodium.

Conclusion

The experiments in normal rat brain and glioma revealed: chloride *in vivo* is as visible as the sodium MR signal. However, the bi-exponential FID and limited sampling size dramatically affect the quantification of MR images and needs to be corrected according to the developed Matlab model. The finding of increased chloride concentration in glioma correlates with the hypothesis stating a critical role of chloride for tumor progression.

Acknowledgements

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References

[1] Schepkin, V.D., *et al.*, Magnetic Resonance Materials in Physics, Biology and Medicine (MAGMA), accepted.