Ultra-High-Field Sodium Imaging of the Human Brain at 9.4 Tesla

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Introduction

The second most abundant MR active nucleus in the human body is sodium (23Na). Although its role in the physiology of the human body is fundamental [1], its low concentration and fast bi-exponential relaxation have always limited its use in neuroimaging. A great opportunity to establish sodium MRI as a neurophysiological research tool is given by ultra-high-field MRI (UHF-MRI). In combination with dedicated RF coils, such as phased-array receivers, and signal-to-noise efficient sequences such as Twisted Projection Imaging (TPI) [2], sodium UHF-MRI opens new horizons for the understanding of neurodegenerative mechanisms of diseases such as Alzheimer's disease or Multiple Sclerosis. In this preliminary study, results recently obtained on a whole-body 9.4T scanner are shown, demonstrating the advantage in terms of resolution and SNR efficiency compared to 4T.

Methods

An informed volunteer was scanned under an IRB approved protocol using the same TPI sequence implementation on both 9.4T and 4T whole-body Siemens (Erlangen, Germany) machines**.** The scanning protocol was set up in order to achieve a nominal isotropic resolution of 2mm, using a readout length of 25ms, repetition time of 100 ms and an echo time, TE, of 0.4 ms. The total acquisition time was 13 mins and 50 seconds. The coil used for the scan at 9.4T (Fig. 1) included an outer high-pass, 16-rung birdcage and an inner eight-element receive array assembled in two concentric, tightly-fitting cases. The birdcage was actively detuned by PIN diode switches in each rung. The inner receive elements consist of unshielded loops which employ a common leg structure and preamplifier decoupling (<20dB). During transmission, the receive elements are likewise detuned via PIN diodes at the preamplifier input terminals. At 4T a dual 1H/23Na birdcage head coil (Rapid Biomed, Rimpar, Germany) was used. An anatomical scan acquired with a standard MP-RAGE was performed at 4T. Sodium images from 9.4T were Hanning filtered and the bias-field correction of SPM8 was used to eliminate coil sensitivities. MP-RAGE and sodium images were co-registered using SPM8.

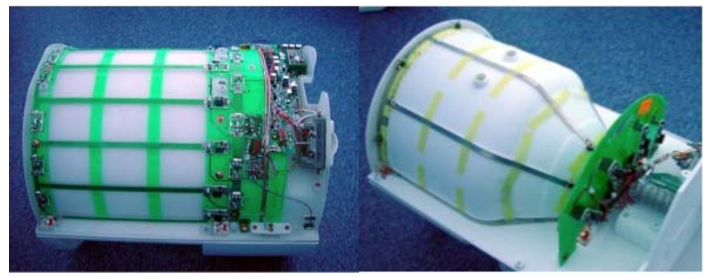

Figure 1. Left: picture of the 16 rung transmit birdcage coil including PIN diodes attached to each rung . Right: upper half of the 8 channel phased-array coil. The unshielded loops had a common leg. PIN diodes and preamplifiers are mounted on the fan-shaped PCB board.

Results and Discussion

Figure 2 shows transverse slices of the co-registered images. The sodium image at 4T shows recognisable CSF but SNR in tissue is too low to see any structures. The SNR of the 9.4T images is very good. The nominal 2mm resolution cannot be achieved as signal decay, sampling of a spherical k-space and Hanning filtering lower the resolution. However, the spatial resolution still allows for resolution of anatomical details that are completely unobservable at 4T.

Conclusion

Sodium imaging at 9.4T enables a significant improvement in signal-to-noise ratio. High spatial resolution using dedicated phased-array coils allows for resolving of tiny brain structures that could not be resolved in sodium images previously. Ultra-high field sodium imaging could open new perspectives in investigation of neurophysiological diseases.

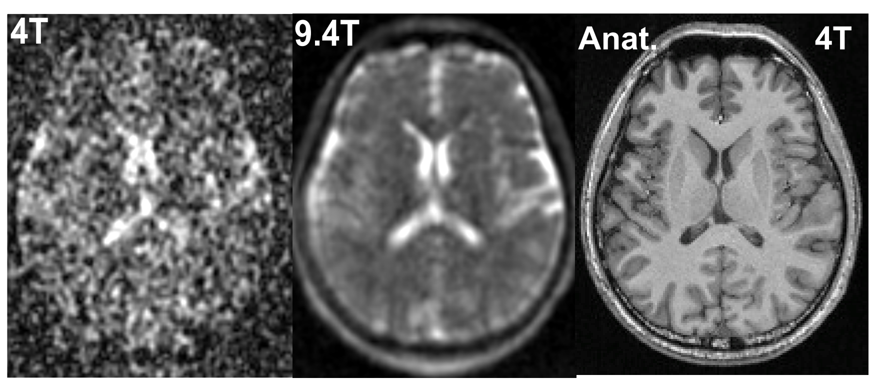

Figure 2. Left: image acquired at 4T. Centre: image acquired at 9.4T. Right: anatomical scan acquired at 4T

References

[1] Boada et al., C Top Dev Biol 2005 [2] Boada et al. MRM 1997