Simultaneous B_1 Mapping and Tissue Sodium Content Quantification by MRI at 3 Tesla

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Target Audience

Researchers and clinicians interested in the quantification of sodium tissue concentration, e.g. for stroke, MS and tumor diagnosis.

Introduction

The tissue sodium content (TSC) is a sensitive measure for pathological changes[1] and can be detected noninvasively by MRI. For the absolute quantification of TSC B_1 inhomogeneities have to be corrected, which is not established beyond the scope of research yet. For B_1 correction up to now, either the double-angle method[2] (DAM) is used, which also yields spin-density weighted images or, additionally, B_1 mapping with other techniques has to be performed. This prolongs the measurement significantly. However, the DAM has been shown to be not suitable for ^{23}Na MRI due to high noise susceptibility[3]. Most accurate maps can be achieved with the phase-sensitive method (PS)[4]. We propose a method for simultaneous B_1 mapping and spin-density weighted imaging without prolonging the measurement time in order to enhance accuracy and clinical field strengths.

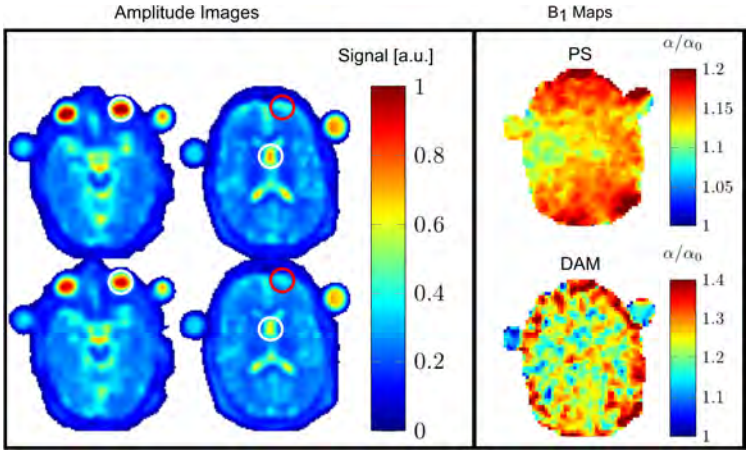

Figure 1: *Left: Density-weighted ^{23}Na images of a human head from PS method (top) and DAM (bottom). Both base images of the B_1 mapping procedures were averaged. Data from PS show higher SNR (white circles). The smaller B_1 field susceptibility is also seen at the frontal region (red circle). Right: In-vivo B_1 maps by PS (top) and DAM (bottom). The PS map is very smooth, which is reflects the actual variation. DAM exhibits hotspots, which are unlikely to result from field variations.*

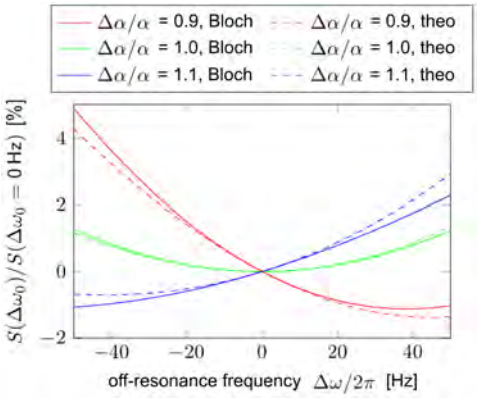

Figure 2: *Bloch simulation (solid lines) and theoretical calculations (dashed lines) for the change of signal amplitude of the PS data as function of B_0 and B_1 inhomogeneity. Amplitude variations are only about 2% for moderate B_0 inhomogeneities and the influence of B_1 variations is almost symmetric.*

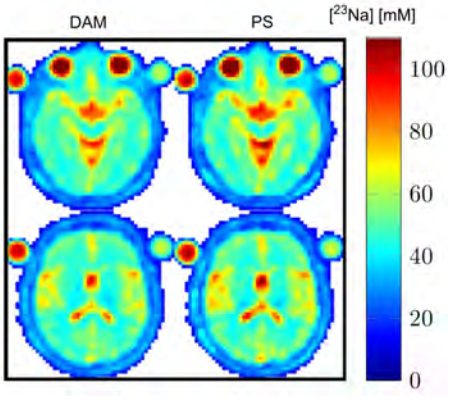

Figure 3: *TSC maps by the DAM (left) and PS method (right). Correction for B_1 inhomogeneities was applied. The higher concentration in the CSF of the PS data is in accordance with literature, whereas the DAM yields an underestimate. Smaller structures are generally better reproduced in PS data due to higher SNR.*

Methods

For all measurements a 3D radial density-adapted sequence[5] was used on a 3 T whole-body scanner (Magnetom TIM Trio, Siemens Healthcare, Erlangen, Germany) employing a double-tuned (^{1}H/^{23}Na) birdcage head coil (Rapid Biomedical GmbH, Würzburg, Germany). In-vivo B_1 maps of three healthy volunteers were acquired using the DAM and the PS method with echo times of 0.24/0.46 ms, flip angles of 45°/ 90° (DAM) and a 90° base excitation (PS) at a nominal resolution of 4 mm. In order to achieve a completely density-weighted signal, a repetition time of 160 ms was chosen resulting in a measurement time of 20 min. Possible deviations of the PS amplitude due to B_0 and B_1 inhomogeneities were analyzed by Bloch simulations and theoretical calculations. Furthermore, the signal loss due to the longer echo time was determined. The TSC of white matter (WM) and vitreous humor (VH) was measured exemplarily using the B_1 corrected amplitude data.

Results and Discussion

Relative SNR of the amplitude data (cf. **Figure 1**, left) was measured in CSF. For the PS method, a 13% higher SNR was obtained. The standard deviation in WM over three slices was found to be half as high for PS compared to DAM. The B_1 maps by the PS method (cf. **Figure 1**, right) show higher SNR and smoother field variation, which reflects the actual slow B_1 inhomogeneities more accurately. The deviation in signal amplitude as a function of the off-resonance was found to be 2% (cf. **Figure 2**) in the case of moderate off-resonances (≈30 Hz). This can be corrected using a B_0 map or even neglected. The TSC in a healthy human head was determined (cf. **Figure 3**) to be 36±1 mM / 35±1 mM in WM and 120±3 mM / 134±3mM in VH as reported elsewhere with the DAM[6]. The variation of the value for VH may be due to residual field effects.

Conclusion

A method for simultaneous B_1 mapping and imaging using the phase-sensitive method is proposed. Maximal time-efficiency is realized since B_1 variations are encoded into the signal phase while the concentration information is determined from amplitude as usual. A 10% higher SNR compared to the more often used DAM and a smaller susceptibility to B_1 inhomogeneities are further advantages. Employing the proposed method for TSC quantification, measurement time can be significantly reduced and at the same time the accuracy is increased. This result could allow ^{23}Na MRI to be better incorporated into clinical studies and routine.

References

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