Now That's a Hippo! A Clinical Imaging Protocol for the Human Hippocampus at 7T

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Introduction

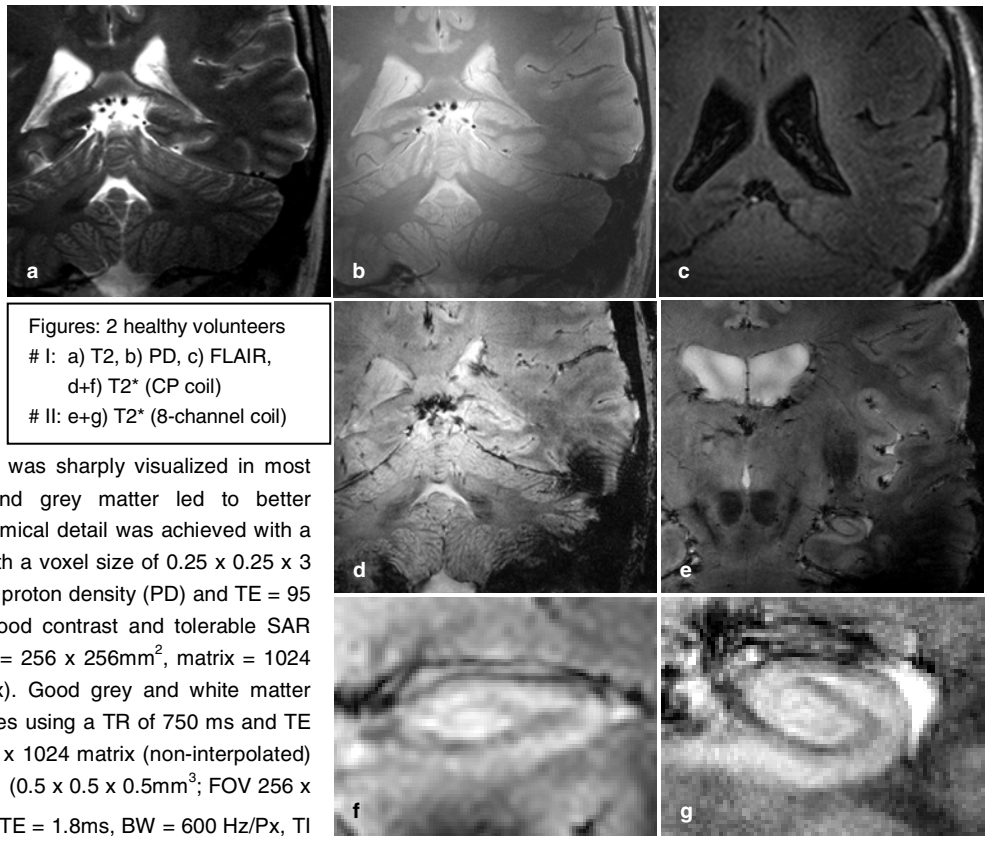
The introduction of high field magnetic resonance (MR) imaging systems (7 Tesla) for human imaging requires the adaptation of clinical sequences from 1.5 or 3 Tesla scanners for optimal results. Utilizing the advantages, i.e. higher signal, and mastering the challenges, i.e. B1-field inhomogeneity and SAR issues, of the fairly new technique is critical for gaining importance for clinical use. The purpose of this study was to find imaging parameters for the hippocampal area depicting its structure with a cutting-edge resolution.

Methods

All measurements were performed on a whole-body 7 Tesla scanner (Magnetom 7T, Siemens, Erlangen, Germany) equipped with a gradient system capable of 45 mT/m maximum amplitude and a slew rate of 220 mT/m/ms. Five volunteers were used to optimize coronal proton-density-, T2-, T2*-, FLAIR-, and T1-3D-MPRAGE sequences regarding contrast and resolution. Four volunteers were imaged with a transmit-receive CP birdcage head coil (Invivo Corp., Gainesville,FL,USA) and one with an 8-channel transmit-receive birdcage head coil (Rapid Biomedical, Würzburg, Germany). The imaging parameters were chosen to optimize the demarcation and internal contrast of the hippocampal areas. Due to changed T1- and T2- relaxation times, TE and TR as well as TI had to be reconsidered for best image quality. Limited coverage due to SAR restrictions had to be overcome by appropriate protocol modifications. The images were compared between the two coils and to 1.5 Tesla images. Two blinded senior radiologists evaluated in consensus: delineation of the hippocampal structure, recognition of internal hippocampal structures, and character and amount of overlying artifacts.

Results and discussion:

All five imaging sequences were successfully performed, and the depiction of the hippocampal area was achieved in all 5 subjects. The region of interest could be covered by all 5 sequences in a reasonable timely manner (TA = 5 to 15 min). Especially spin echo sequences were confronted with SAR limitations which had to be overcome. One strategy was to use gap filling (gap = 100%) and cover the region of interest with two concatenations. Hippocampal structures were well visualized at all slice positions without any significant disturbance by artifacts (i.e. susceptibility artifacts). The hippocampal sulcus was sharply visualized in most sequences. New contrasts between white and grey matter led to better visualization compared to 1.5 Tesla. Good anatomical detail was achieved with a double echo turbo spin echo (TSE) sequence with a voxel size of 0.25 x 0.25 x 3 mm^3. Here, a TR of 5000 ms and TE = 11 ms for proton density (PD) and TE = 95 ms for T2 weighting was needed to achieve good contrast and tolerable SAR values (10 slices, distance factor = 100%, FOV = 256 x 256mm^2, matrix = 1024 x1024 int., flip angle = 150°, BW = 255 Hz/Px). Good grey and white matter contrast was especially obtained in T2*-sequences using a TR of 750 ms and TE of 20.4 ms; a FOV of 173 x 230 mm^2 and a 768 x 1024 matrix (non-interpolated) resulted in 0.2 x 0.2 x 2.5 mm^3 voxels. MPRAGE (0.5 x 0.5 x 0.5mm^3; FOV 256 x 256mm^2, real matrix = 512 x 512, TR = 2750ms, TE = 1.8ms, BW = 600 Hz/Px, TI = 1200ms, flip angle 10°) allowed good grey / white matter differentiation, and was thus good in depicting the hippocampal mantle. In the one volunteer imaged with the 8-channel array, higher signal to noise improved image quality significantly. The signal gain was most significant for the T2* sequence.



Figures: 2 healthy volunteers
I: a) T2, b) PD, c) FLAIR, d+f) T2* (CP coil)
II: e+g) T2* (8-channel coil)

Conclusion:

Utilization of the significantly higher signal-to-noise ratio at 7 Tesla is possible through considerable modifications of the sequence parameters. The described examination protocol permits the complete high resolution imaging of the hippocampal area. Mastering the new contrasts at 7 Tesla was the most demanding part of this study, i.e. due to changed T1-relaxation times and highly emphasized T2* effects and artifacts. A second challenge were SAR restrictions, which often limited field-of-view coverage. The spin-echo based FLAIR sequence was most prone to SAR limitations, forcing a longer TR than desired and the use of gap filling to artificially lengthen the scan time. MPRAGE covers the hippocampal area as part of a high resolution isotropic 3D whole-brain imaging protocol. Reducing SAR and scan time remains challenging. The multi-channel coil showed very promising initial results; aside from the signal to noise improvement, such a design enables parallel imaging, which will certainly be a valuable contribution in the future.

Acknowledgements: this research was funded in part by the Dr. Werner Jackstädt Foundation, Wuppertal, Germany.