First clinical epilepsy imaging at 7 Tesla.

T. Breyer[1], J. M. Theysohn[2], S. Maderwald[2], O. Kraff[2], M. Ladd[2], F. Woermann[3], A. Ebner[4], M. U. Schlamann[1], M. Forsting[1], and I. Wanke[1]

[1]Institute of Diagnostic and Interventional Radiology and Neuroradiology, Essen University Hospital, Essen, NRW, Germany, [2]Erwin L. Hahn Institute of MRI, University of Duisburg-Essen, Essen, NRW, Germany, [3]MR Imaging Department, Bethel Epilepsy Center, Bielefeld, NRW, Germany, [4]Mara Clinic I, Bethel Epilepsy Center, Bielefeld, NRW, Germany

Introduction

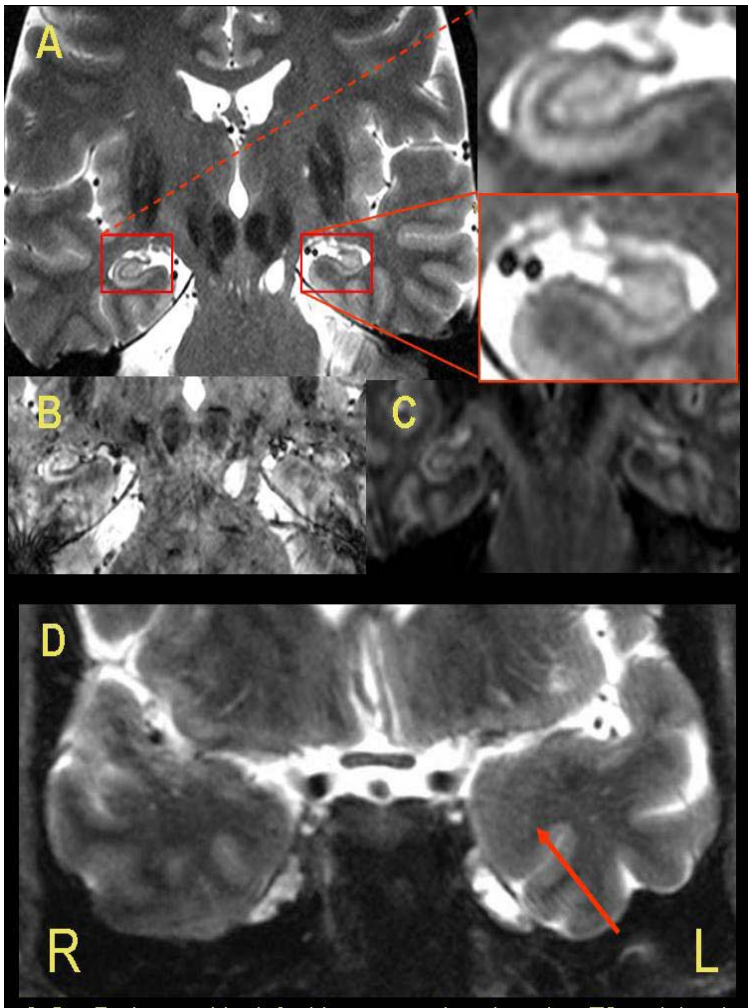
Even very small abnormalities of the cortical structure, either acquired or developmental, can cause severe epileptic syndromes. Besides traumatic or ischemic lesions, major causes of medically intractable focal epilepsy include hippocampal sclerosis (HCS), focal cortical dysplasias (FCD) and tumors. The precise anatomical delineation of these lesions is crucial for diagnosis and mandatory before possible surgical treatment. With the advent of human 7 Tesla MR imaging, the signal-to-noise ratio (SNR) and thus spatial resolution to delineate small lesions, especially the hippocampal (sub-) structures, has further improved. The purpose of this study is to apply and test this new technique for the first time in patients with known epileptic lesions.

Methods

The local institutional ethical committee approved this study. Ten patients were investigated with known epileptic lesions, HCS and/or FCD, as shown by clinical 1.5 Tesla MR imaging. All measurements were performed on a whole-body 7 Tesla scanner (Magnetom 7T, Siemens Medical Solutions, Erlangen, Germany) equipped with a gradient system capable of 45 mT/m maximum amplitude and a slew rate of 220 mT/m/ms. Measurements included a double echo turbo spin echo (TSE) sequence (TR = 5000 ms, TE = 11 ms (proton density), TE = 95 ms (T2-weighted), 10 slices, distance factor 100%, FOV = 256 x 256 mm^2, matrix = 1024 x 1024 (interpolated), voxel size 0.25 x 0.25 x 3 mm^3, flip angle 150°, BW = 255 Hz/Px), T2*-weighted (TR = 750 ms, TE = 20.4 ms, 15 slices, distance factor 100%, FOV = 230 x 173 mm^2, matrix 768 x 1024 (non-interpolated), voxel size 0.2 x 0.2 x 2.5 mm^3, BW = 30 Hz/Px), T1-weighted 3D-MPRAGE (TR = 2750 ms, TE = 1.8 ms, 256 slices, FOV = 256 x 256 mm^2, acquired matrix = 512 x 512, voxel size 0.5 x 0.5 x 0.5 mm^3, flip-angle 10°, BW = 600 Hz/Px, TI = 1200ms). Acquisition times varied between 2:31 and 15 minutes per sequence. The specific absorption rate (SAR) limitations were overcome by gap filling (distance factor 100%) and coverage of the region of interest with multiple concatenations artificially prolonging the scan time. Measurements were performed with an 8-channel transmit-receive head coil (Rapid Biomedical, Würzburg, Germany).

Results and discussion

Human, clinical MR imaging at 7 Tesla is feasible in patients with epilepsy. All patients well tolerated imaging at 7 Tesla and all sequences were successfully performed. The prior diagnosis at 1.5 Tesla was confirmed in all patients, but patho-anatomical details clearly improved with 7 Tesla in T2- and T1- but especially in T2*-weighted images. The significantly higher SNR ratio at 7 Tesla permits high resolution imaging, but SAR restrictions still limit the overall field-of-view coverage. The high susceptibility effects provided “new” contrasts and rich anatomical details in T2- and T2*-weighted images i.e. of the dentate nucleus in the hippocampus. Lack of internal structural details clearly indicated hippocampal sclerosis. Susceptibility artifacts caused by air in the sphenoid sinus and petrous bone affected imaging quality in individual patients in coronal sequences.



A-C: Patient with left hippocampal sclerosis, T2-weighted, coronal sections (A) and magnified hippocampi, T2*-weighted (B), FLAIR-weighted (C). **D:** Patient with focal cortical dysplasia of the left amygdala and parahippocampal gyrus (arrow), coronal T2-weighted.

Conclusion

Clinical 7 Tesla MR imaging offers new contrasts in combination with a very high spatial resolution providing deeper insights into anatomical and pathological detail of epileptogenic lesions, i.e. the internal hippocampal structure. Improvements in transmit-receive multi-channel coil technology in combination with new transmitting techniques will further improve the value of imaging at high magnetic fields. This is very promising since epileptic lesions can be very small and signal changes in cortical dysplastic lesions minute. However, further studies will be necessary to document the translation of high magnetic field imaging benefits into clinical improvements for patients with epilepsy.