Examples of clinical imaging at 7T: Successes and Challenges

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Purpose: To explore the clinical potential of 7T MRI.

The increasing presence of 7T MRI is rapidly advancing neuroimaging research. However, corresponding progress of 7T on clinical neurological disease is lagging, likely due to the current lack of FDA approval. Here we present an imaging comparison of 6 different types of clinical lesions between 7T and lower field strengths, using an IRB protocol explicitly allowing this comparison. This method does not affect patient care, yet permits an ongoing exploration of how imaging characteristics compare between ultrahigh field and clinically approved field strengths.

Methods:

An IRB was obtained permitting 7T imaging of patients with neurological disease for the strict purpose of comparing the imaging of a lesion previously seen at lower field MRI (i.e. 1.5T or 3T) to the imaging seen at 7T. Thus, 7T images were not permitted to influence medical care on the basis of diagnosis. 7T exams were obtained on a newly installed 7T scanner (MAGNETOM 7T, Siemens), using a 32-channel phased array head coil (Nova Medical). Typical scanning parameters are: 3D T1-MP2RAGE: Sagittal acquisition, TR/TE = 6000/2.99 ms, TI1/TI2 = 800/2700 ms, Flip angle1/ Flip angle2 = 4/5°, 0.75 mm3 iso-voxel resolution, 192 slices, Grappa acceleration factor = 3, Total acquisition time (TA) = 9 min 8 sec; 2D T2*-GRE: Axial or Coronal acquisition+, TR/TE = 2290/17.8 ms, Flip angle = 25°, in-plane resolution = 0.38 mm2, slice thickness = 1.5 mm, 30 slices, no gap, GRAPPA acceleration factor = 2, TA = 10 min 12 sec. 2D FLAIR: Trans axial acquisition, TR/TE = 9000/124 ms, TI = 2600 ms, in-plane resolution = 0.75 mm2, slice thickness = 2 mm, 45 slices, 30 % gap, GRAPPA acceleration factor = 3, Turbo factor = 11, TA = 3 min 32 sec.

Results and Discussion:

To date, a total of 29 patients have been scanned with 6 different types of neurological lesions: 12 with epilepsy; 9 with TBI; 3 with multiple sclerosis; 3 with ALS; 1 with amyloid angiopathy; and 1 with a cavernous malformation. As with routine non-7T clinical imaging, the detailed protocol of sequences used varies depending on the disease. Most patients received FLAIR, SWI, GRE, MP2RAGE, T2*W, resting-state connectivity, and HARDI. Total time in the scanner was about 60 minutes for most patients (between 45 and 75 minutes). Two examples of findings seen better at higher field are shown below: the left is a patient with Multiple Sclerosis. 7T GRE nicely reveals the coalescent white matter lesions to be a superposition of numerous circular lesions with vessels at their center. The right shows a patient with TBI where a cortical microhemorrhage at 3T SWI was only appreciated at 7T SWI due to its high resolution and sensitivity to blood products. Other examples of difference were: TBI lesions at low field found to be a developmental venous anomaly at 7T; other TBI showing more extensive injury at 7T; location of traumatic microhemorrhages shown to be at gray-white junction at 7T; increased conspicuity of stigmata of motor neuron disease (e.g. ALS) at 7T. At this time the principal advantages of 7T over lower field are smaller voxel size permitting higher resolution imaging and higher sensitivity to chronic blood products. In addition there is increased BOLD signal, which greatly amplifies resting state studies and task-related fMRI. Significant challenges remain, principally the FLAIR sequence, which appears significantly inhomogeneous through the brain compared with 3T. Also, there is generalized signal loss in the anteromedial temporal lobes and posterior fossa. Future work will use parallel transmit to address these issues. Patients with brain tumors and movement disorders will be examined.

Conclusion:

A recent IRB strategy permits direct comparison of patients with neurological disease from 7T to lower field. To date 29 patients with disease categories have been images. The two principal advantages of 7T that could potentially benefit clinical care: smaller voxels that permit better detail; and stronger susceptibility effects that improve visualization of chronic blood products. Future challenges are improved uniformity of FLAIR sequences.