Establishing a Comprehensive Multiple Sclerosis Imaging Protocol at 7.0T

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Introduction: Several studies have shown that the detection of multiple sclerosis plaques is improved at higher magnetic fields such as 3.0T if compared with 1.5T. Triggered by the positive experiences that have been obtained at 3.0T, efforts are made to allow clinical MR imaging at even higher magnetic fields. MR systems operating at a field strength of 7.0T are meanwhile available and are ready for clinical use. Our aim was to do the first steps for establishing an MRI protocol that is suitable for imaging multiple sclerosis patients at 7.0T. Prerequisite was to include all pulse sequences that are required for diagnosing MS by MR imaging and for rating disease activity in a clinical setting. Long term goal is to investigate whether 7.0T imaging may help further improve our ability to diagnose and stage multiple sclerosis, and to provide a sensitive tool for therapy monitoring.

Materials and Methods: First experiences were obtained in 6 healthy volunteers (mean age, 35 years, all male); thereafter, 2 patients (one male, one female, aged 56 and 49 years) with confirmed multiple sclerosis underwent MR imaging at 7.0T with the "optimized" protocol. All imaging studies were performed on a 7.0T system (Philips Medical Systems, Cleveland, OH, USA). To get a (very preliminary) idea of the diagnostic yield, both patients and 3 of the 6 volunteers also underwent MR imaging at 3.0T and at 1.5T, with the same or equivalent imaging protocol. Care was taken to have the pulse sequence parameters comply with the requirements made by the International Guidelines of the National Multiple Sclerosis Society. The final protocol consisted of the pulse sequences: Axial FLAIR, axial and sagittal, high-resolution thin-section T2-weighted TSE, axial T1-weighted TSE, T1-weighted 3D Turbo Gradient Echo (TFE), T1-weighted Modified Driven Equilibrium Fourier Transform (MDEFT). T1-weighted pulse sequences were obtained prior to and after injection of contrast agent (0.05 mmol/kg BW Gd-DTPA, i.e. half standard dose).

Results: Since no parallel imaging was available for 7.0T at the time when these studies were performed, RF power deposition, and image homogeneity across the imaging field of view were the main concerns. RF power management was achieved by compromising on the acquisition speed (prolongation of TR) and on anatomic coverage (reduction of number of sections in T1-weighted images). In addition, refocusing RF pulse modulation ("Flip Angle Sweep") was used to reduce RF deposition in all pulse sequences. High order shimming was successfully used to improve image homogeneity. We were able to keep pulse sequence parameters regarding geometric image resolution (slice thickness, imaging matrix) equivalent to the respective 3.0T and 1.5T imaging protocols. Due to B1 inhomogeneities and dielectric effects, there was only limited visibility of the posterior fossa structures (arrow in Fig. 1a). Some "shadowing" was also observed in the lowermost parts of the brain (basal temporal lobes), in particular in gradient echo images (T1-weighted TFE); this latter effect did, however, not interfere with the diagnostic utility of the images in these areas. Otherwise, image homogeneity was considered excellent (see Figure 1) and comparable to the 3.0T images. Image contrast was comparable, with the notable exception of T1-weighted *TSE* (not: TFE or MDEFT) images. T1-w TSE images exhibited a reduced grey/white matter contrast because, in order to accommodate 20 sections within SAR limits, we had to increase the TR to 1000 ms. In addition, the signal intensity loss in iron-containing cerebral structures like the basal ganglia, red nucleus or substantia nigra was more pronounced at 7.0T (comparable to the difference between 1.5T and 3.0T). Conspicuity of enhancing structures (choroid plexus, MS plaques) was equivalent to 3.0T, with the notable inclusion of also the T1w TSE images. Overall, 7.0T image quality in the volunteers as well as in the two patients was rated excellent. Visual SNR was higher compared with the same patients' examinations obtained at 3.0T. In the two patients, conspicuity of MS plaques and the overall number of demyelinating lesions ("black holes" as well as fresh ED plaques) were comparable.

Conclusion: These very initial results suggest that 7.0T imaging of multiple sclerosis patients is feasible, even without parallel imaging techniques. Coverage of the posterior fossa is still insufficient. With the advent of multichannel RF transmit coils and tailored pulses there is reason to assume that this will improve in the foreseeable future. This study has to be considered as a "proof of principle" of clinical MR imaging at 7.0T. Next step is to investigate the stability of the protocol in an entire cohort of patients, and to develop pulse sequences that should yield higher anatomic or contrast resolution compared with 3.0T.

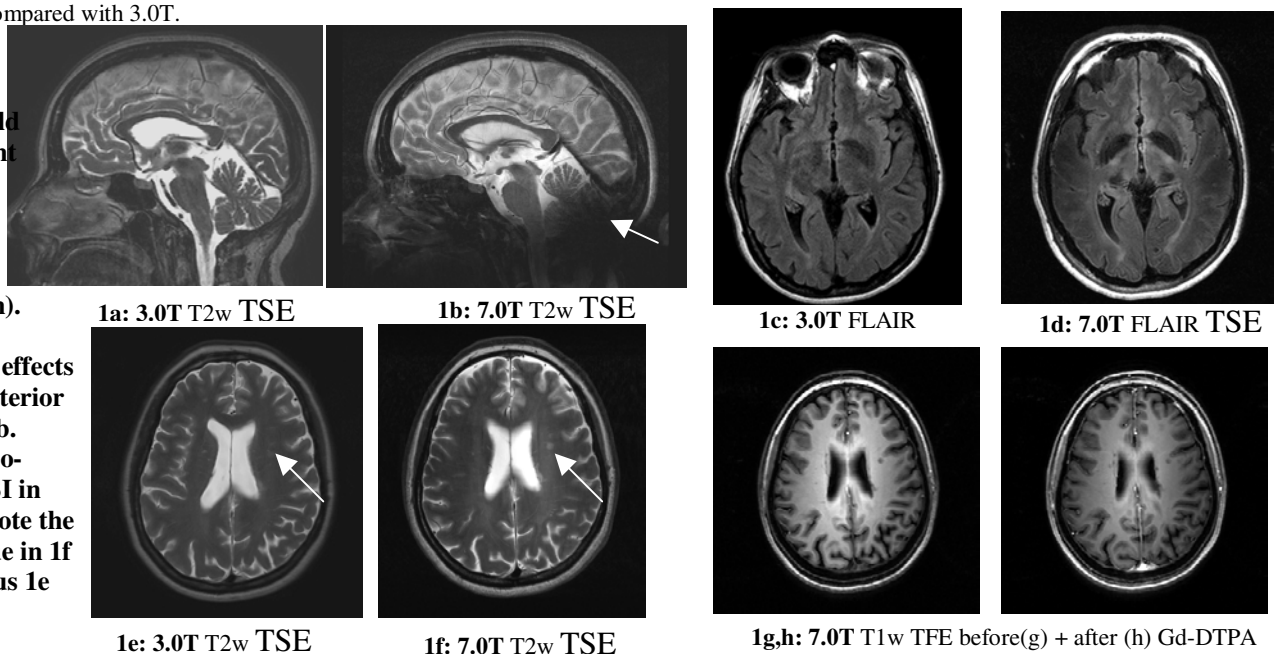

Fig. 1: 49-year-old MS patient imaged at 3.0T (1a,c,e) + at 7.0T (1b,d,f,g,h). Note the dielectric effects in the posterior fossa in 1b. Note homogeneous SI in b,d,f-h. Note the MS plaque in 1f (7T) versus 1e (3T)

1a: 3.0T T2w TSE

1b: 7.0T T2w TSE

1c: 3.0T FLAIR

1d: 7.0T FLAIR TSE

1e: 3.0T T2w TSE

1f: 7.0T T2w TSE

1g,h: 7.0T T1w TFE before(g) + after (h) Gd-DTPA