Is every multiple sclerosis lesion a "black hole"? Comparison of T1-weighted MRI at 1.5T and 7.0T

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INTRODUCTION: In current clinical practice, T_2-weighted Magnetic Resonance Imaging (MRI) is commonly applied to quantify the accumulated MS lesion load. With the lesion detected, T_1-weighted techniques are used to depict edema, blood brain barrier breakdown after contrast enhancement, and irreversible brain tissue damage (commonly called "black holes" due to hypointense - if not fully suppressed - signal in the lesions). Black holes are histopathologically associated with axonal loss and severe tissue destruction (1). In addition, double-inversion-recovery (DIR) techniques were developed to improve the sensitivity also for cortical lesions. To our knowledge, recent 7T studies have not considered T_1-weighted MPRAGE for cortical lesion detection (2, 3, 4). For all these reasons this work demonstrates the potential of ultrahigh field 3-D T_1-weighted imaging using magnetization-prepared rapid acquisition and multiple gradient echoes (MPRAGE) for the detection and characterization of white and grey matter pathology in multiple sclerosis (MS).

DESIGN/METHODS: Seventeen MS patients with relapsing-remitting disease course (mean SD age: 40.3±6.5years; mean SD disease duration: 5.2±3.9years; mean range EDSS score: 2.2, 1.0-4.5) and nine matched healthy controls were investigated at 7T (Siemens Magnetom, Erlangen, Germany), using a 24 channel receive head coil (Nova Medical, Wilmington, MA, USA). The imaging protocol included 2D FLASH (TE 25.0ms; TR 1820ms; acquisition time 12:11mins, spatial resolution 0.5 x 0.5 x 2mm3) and fluid attenuated sequences (TIRM; TE 90ms; TR 16000ms; TI 2925.5ms, acquisition time 12:50mins, spatial resolution 1.0 x 1.0 x 3.0mm^3). For 3D T_1-weighted imaging, a magnetization-prepared rapid acquisition and multiple gradient echo technique (MPRAGE; TE 2.98ms; TR 2300ms; TI 900ms, acquisition time 9:14mins, spatial resolution 1.0 x 1.0 x 1.0mm^3) was used. For comparison, all subjects were scanned on a 1.5T system (Siemens Avanto). White-matter (WM) lesions and lesions extending into the subcortex (mixed lesions) of a diameter smaller than 2mm were excluded from the study in order to avoid false positives.

RESULTS: In total, we detected 435 cerebral lesions in the patient cohort (range: 8 – 72 per patient, mean: 25,6), but none in healthy controls. In eight patients, we found four cortical and 23 mixed cortical/subcortical lesions. At 7T, each lesion detected in T_2- and or DIR sequences was also clearly delineated in the corresponding MPRAGE images. In contrast, at 1.5T, MPRAGE only revealed 284 lesions. Furthermore, no cortical and only 15 mixed lesions were visualized by T_1-weighted images at 1.5T.

CONCLUSIONS: At ultrahigh field strength, T_1-weighted MPRAGE is highly sensitive in detecting MS lesions as hypointensities in the white as well as the grey brain matter. Our results indicate a structural damage of every lesion depicted, which is in accordance with post-mortem histopathological studies, that demonstrated axonal transection in each MS lesion, visible as terminal axonal ovoids (5). Furthermore, at 7T, MPRAGE clearly delineated each cortical lesion that was visualized in any other MRI sequence at 1.5T or 7T.

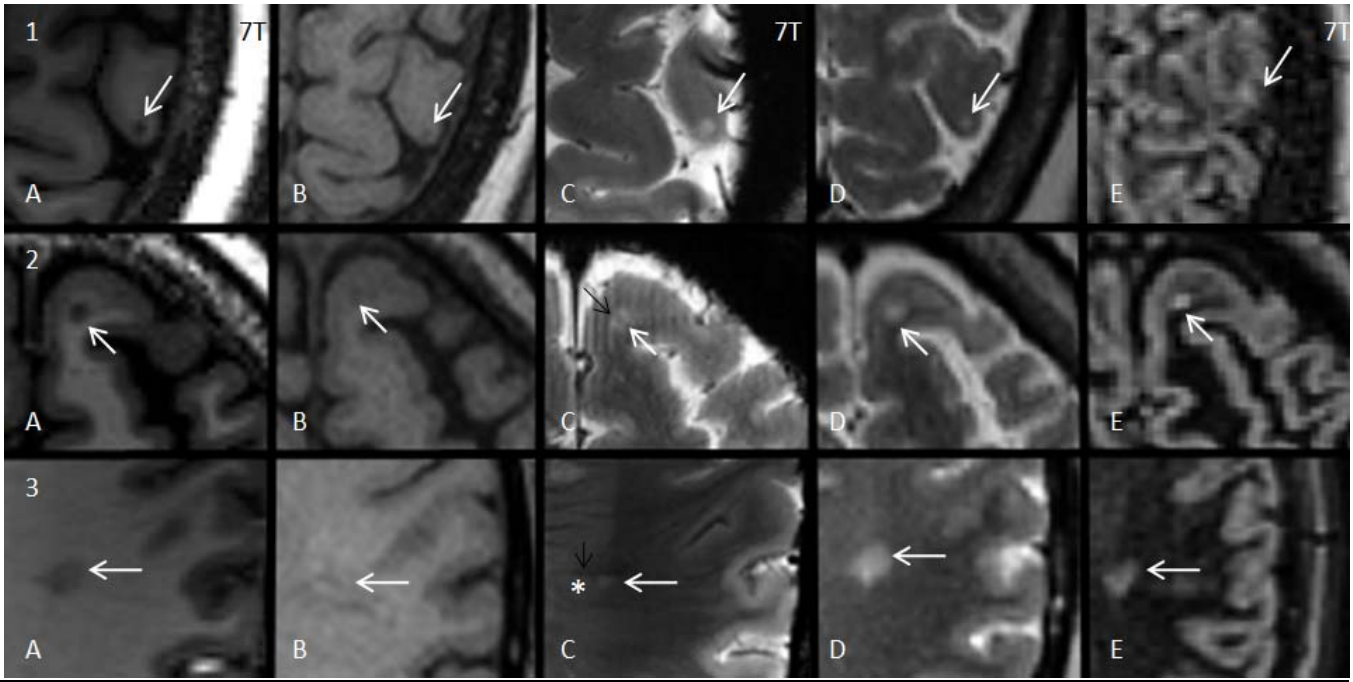

FIGURE 1: Examples of cerebral MS lesions in 1) grey matter, 2) subcortex, and 3) white matter.

A) 7T, MPRAGE delineates each lesion as a distinct hypointensity. **B)** 1.5T T_1-MPRAGE infrequently depicts lesions, that are clearly detected by **D)** 1.5T T_2-weighted, or **E)** DIR sequences. **C)** 7T FLASH reveals a perivascular setting (black arrow 2C, 3C) and often a surrounding hypointense rim (asterisk 3C).

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