Ultra-High Field Clinical Brain MR Imaging: Challenge and Excitement

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Introduction: From the neuroimaging perspective, the overall quality, capability and potential as well as the technical challenges have proportionally increased with the increase in the field strength of MR scanners up to 3T. The question remains where the optimal field strength for CNS imaging may be. The purpose of this study was to demonstrate and discuss the potential, challenges and pitfalls for various CNS pathologies based on our experiences in both 7 T and 8 T whole body scanners of ultra-high field (UTF) brain imaging.

Material and Method: A total of 152 patients were studies on either a 7T (N = 51) or an 8T (N = 101) MR scanner. All patients had signed IRB approved consent forms for various CNS pathologies. These included primary CNS tumors, brain metastasis, multiple sclerosis, ischemia and degenerative diseases. Compared to the 1.5T MR, UTF images were assessed for lesion detection, delineation, characterization and the quality of the functional images, and the underlying pathological micro-environment including the micro-architecture, micro-vascularity, and micro-hemorrhage.

Results: UTF clinical MR scanners have shown several promising potentials. For clinical applications, the major advantages include improved signal-to-noise-ratio (SNR) and susceptibility contrast. Most of all, the UTF clinical MR provides an excellent opportunity to assess the micro-environment including the micro-architecture, micro-vascularity, and micro-hemorrhage associated with the underlying pathophysiology. Magnetic susceptibility can be either advantageous or disadvantageous for ultra-high field MR imaging. By taking advantage of the susceptibility of deoxyehmoglobin, microvasculature as small as 100 mm can be depicted on the UTF gradient echo image (A), which are not seen on the 1.5T (B). Conversely, magnetic susceptibility differences between air and tissue and resultant B_o inhomogeneity, causes image degradation in form of local signal loss, geometric distortions and banding artifacts. The gain of SNR is also offset by the major technical and clinical challenges associated with the increase susceptibility artifacts due to B_o field inhomogeneity near air/tissue interfaces and RF or B_1.

Conclusion: The implementation of ultra-high field whole body systems in the clinical setting provides many advantages and potentials for CNS imaging, and yet there are many technical and clinical challenges to be overcome. Even with the limited clinical experience, early evidence suggests gains and potential to further improve in CNS imaging.

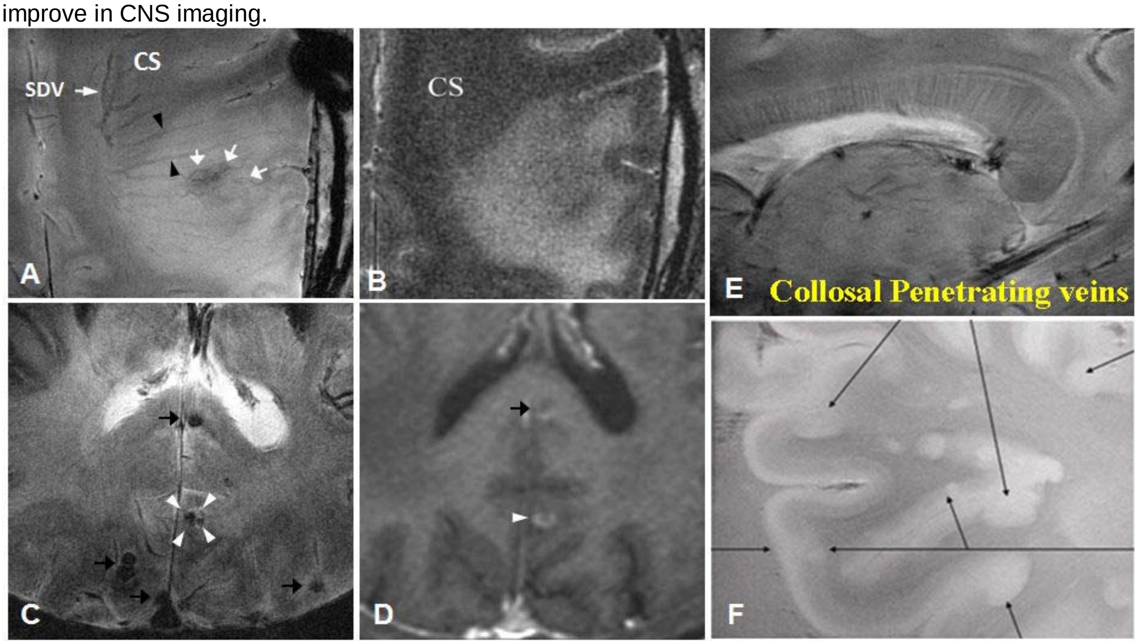

Figure 8T Gradient echo image (A) has much higher SNR and spatial resolution than 1.5 T (B). Normal vessel (arrowheads) and neovasculature (arrows) is seen in UTF (A) but not in B. Multiple metastasis (arrows) are seen in non-contrast 8T MR (C) but not in 1.5 T contrast MR (D). A cluster of 4 small metastasis (C, arrowheads) can only be seen as a single enhancing lesion in (D, arrowhead). Vertical penetrating vessels of Copus collosum is well seen in the 8T MR (E). Rounded cortical MS plaque is well delineated on the 8T MR (F, Arrows)