7 Tesla MRI: Progress towards Clinical Applications in Neuroradiology

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Introduction. The proliferation of 3T MRI scanners in the routine practice of neuroradiology has led to increasing appreciation for the advantages and disadvantages of high-field imaging, especially with the incorporation of advanced physiologic modalities such as perfusion, diffusion, and functional imaging into routine clinical protocols and the widespread adoption of parallel imaging techniques [1]. High-resolution anatomic imaging at 3T, compared to imaging at 1.5T, has improved the characterization of epileptogenic substrates, allowed noninvasive imaging of the intracranial arterial wall, improved depiction of the cranial nerves, and enhanced diagnosis of small, previously undiagnosed perforating artery infarcts and brain parenchymal metastases, to name only a few successful applications. It has also increased the speed with which examinations can be performed, especially when combined with parallel imaging techniques. With the growing number of 7T installations in the research setting, the question has emerged: can similar advantages be realized by transitioning certain applications from 3T to 7T?

Methods. Under approval from our institutional review board and in collaboration with neurologists and neurosurgeons, we have used 7T imaging to successfully study over 300 patients with various neurological diseases over the past 5 years at the University of California, San Francisco [2-7]. The principal advantages of imaging at higher field strength— higher signal-to-noise, increased spectral resolution, and changes in inherent T1, T2, and T2* (susceptibility) tissue contrast— were exploited in order to enhance the depiction of pathology in brain tumors and the post-treatment brain, neurovascular disease, epilepsy, demyelinating disorders, inflammatory disorders, and neurodegenerative conditions including Alzheimer's, Huntington's disease and prion disease. Anatomic protocols specifically developed for these applications included multi-slice and volumetric gradient echo (both magnitude and phase), T2 fast-spin echo, time-of-flight MRA, susceptibility-weighted, proton spectroscopy and diffusion weighted sequences. Resting-state BOLD functional MRI has also been acquired in a subset of patients with these disorders. Custom-made 8- and 16-channel phased-array head coils were used for acquisition, and an array of post-processing techniques developed in house have been used for RF inhomogeneity correction, parallel image acquisition, magnitude and phase image reconstruction, and analysis. In most cases, patients were also imaged at lower field strengths in order to assess the theoretical advantages and disadvantages of 7T.

Results. Representative images will be shown for different disorders to illustrate the improvements that can be achieved with respect to imaging at 3T. Several themes hinting at potential clinical applications in neuroradiology have emerged from our experience. First, 7T imaging allows dramatic improvement in spatial localization of pathology. Precise localization of lesions with respect to the gray-white interface, small cortical and perforating arteries, the medullary venous system and deep gray matter structures may not only enhance the detection of small lesions, but may also increase diagnostic specificity. Second, 7T MRI better reveals the extent and severity of abnormalities than imaging at lower field strengths, even in cases for which MRI has traditionally been unrevealing. For example, widespread changes can be visualized in the irradiated brain on 7T phase and susceptibility-weighted images, and the nature of arterial stenoses can be better characterized at the higher field strength than at 3T or 1.5T. Third, the information provided by 3T and 7T MRI can be complementary. Specifically, sub-millimeter resolution of the entire brain can be prohibitive from the standpoint of time, but when the location of a lesion is known *a priori* it is possible to target 7T images to that location. Finally, 7T MRI may better indicate disease stage and thereby provide new therapeutic targets. Differential microscopic iron deposition in association with demyelinating plaques, for example, may reflect different underlying stages of inflammatory disease.

Conclusion. 7T MRI holds significant clinical potential for the evaluation of neurologic disease. Although it may not ultimately supersede the breadth of 3T techniques due to financial considerations, ultra-high-field MRI promises to be a useful tool for troubleshooting difficult diagnoses at lower field strength and for specific applications such as neurodegenerative diseases.

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