Future Clinical Applications of High Resolution Anatomical Imaging of the Brain at 7.0 Tesla MRI

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Purpose

The purpose of this Educational Review is to show the clinical potential of the anatomically highly detailed images of the brain which can be obtained with 7.0 Tesla MRI. A series of illustrative 7.0 Tesla MRI patient examples will be included.

Outline of content

Since the emergence of MRI as a versatile imaging technique in the beginning of the eighties, field strength for clinical use has increased from < 0.5 Tesla to a wide use of 3.0 Tesla in current clinical practice. The increase in signal to noise at higher field strengths is especially useful for imaging techniques that require a high signal-to-noise ratio (SNR) such as functional imaging techniques (fMRI) and MR spectroscopy, but can also be used for high resolution anatomical imaging, including 3D volume imaging, within acceptable scanning time. Although not widely used clinically, an increasing number of research sites worldwide have the availability of an MRI scanner with a field strength of 7.0 Tesla. There is an active debate if and when 7.0 Tesla MRI may become the field strength of choice for certain clinical applications.

Most of the 7.0 Tesla MRI technical developments and clinical studies involve the brain, especially fMRI which benefits most from an ultrahigh field strength. The backbone of clinical MRI examinations, however, are the anatomical imaging sequences, like T_1-weighted, T_2*-weighted and FLAIR imaging. When 7.0 Tesla MRI finds its way to clinical applications, the main usage will therefore most likely be ultra-high resolution anatomical imaging. In the past years 3D anatomical sequences were developed and optimized that make optimal use of the increased SNR at 7.0 Tesla. These sequences include FLAIR imaging, which is an important sequence in most brain MRI protocols because of the high contrast between brain tissue lesions of any sort and surrounding normal brain tissue. Although not as important as the FLAIR sequence, T_2*-weighted MRI sequences are increasingly used in clinical MRI protocols, for instance for the detection of microhemorrhages. Furthermore, T_1-weighted imaging, especially after contrast administration, can provide just that little extra detail to assess small pathology not seen that clear at lower field strength, for instance atheroma of the intracranial vessel wall. Finally, MR angiography, which is regularly used in clinical practice to assess all kinds of brain pathology, can be obtained with an ultra-high resolution for optimal assessment of even the smallest arteries of the brain. Second, the longer T_1 relaxation times at 7.0 Tesla improve background suppression, resulting in increased contrast between the arteries and the background. In conclusion, high resolution anatomical brain MRI at 7.0 Tesla with sequences such as FLAIR, T_1- and T_2*-weighted imaging and MR angiography may be the potential area where 7.0 Tesla MRI provides additional diagnostic information not found on lower field strengths.

Apart from a review of the current literature regarding anatomical brain MRI at 7.0 Tesla, several patient examples will be given where 7.0 Tesla MRI gave additional diagnostic information or a better delineation of pathology than lower field strengths. Also, normal findings and anatomical variants not seen on 1.5 or 3.0 Tesla will be shown. When possible, comparison with 3.0 Tesla or 1.5 Tesla MR images will be given (Figure) to further illustrate the additional information which can be gained with 7.0 Tesla scanning compared to lower field strength.

Summary

High resolution anatomical imaging of the brain at 7.0 Tesla, even if still in its early years, has the potential to give additional information about pathology and normal anatomical variations when brain pathology is suspected. With its high resolution it will be able to discern abnormalities not seen at lower field strengths, and will be able to contribute to faster and more accurate diagnosing.
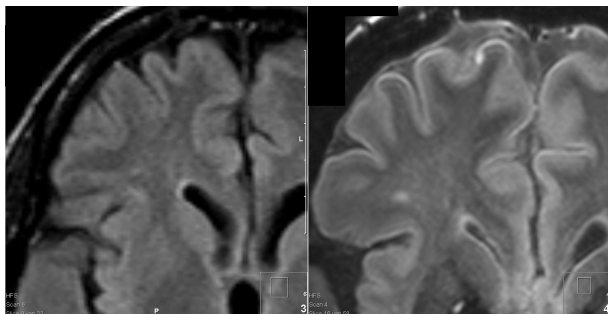
Figure: Comparison of 1.5 Tesla and 7.0 Tesla FLAIR image of the cerebral frontal lobe. There is clear demarcation of gray and white matter and of white matter hyperintensities in the 7.0 Tesla image not seen as clearly in the 1.5 Tesla image. Furthermore, a frontal cortical hyperintensity can be seen on 7.0 Tesla not seen at 1.5 Tesla.