Routine Clinical Brain MR Imaging at 3.0T: Initial Experience

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Purpose
The purpose of this study was to adapt routine clinical MR applications for use at 3.0T. The feasibility of these applications to perform routine brain exams on patients in a clinical setting was then tested.

Introduction
The main advantage of very high field MRI is S/N scales approximately linearly with field strength B_0 in the range of 1.5 to 3.0T. A limitation to be overcome of 3.0T for routine clinical scanning is RF heating, since SAR scales as B_0^2 in the range of 1.5 to 3.0T. Chemical shift and susceptibility (as measured in Hertz) double in this range. Although this can be an advantage for fMRI and Spectroscopy, it is usually a disadvantage for anatomical imaging and gradient-recalled applications like MRA. Finally, the T1 of brain parenchyma increases by 25-40% from 1.5T to 3.0T, so the pulse sequences and protocols must be modified to preserve diagnostic contrast.

With the advent of compact, actively-shielded 3.0T magnets [1], it is now practical to site a 3.0T scanner in a clinical MR suite. Such scanners, however, are not yet routine clinical tools. Most such scanners have been used for clinical research, focusing on the applications of Spectroscopy and fMRI. In order to expand the applications scope of these systems, we developed pulse sequences and protocols for routine anatomical imaging [2], MRA, and diffusion imaging. For example, typical requirements for routine anatomical brain imaging in our practice include whole brain coverage with T1-weighted, T2-weighted, and FLAIR contrast. Each scan must be as short as possible, with 10 minutes considered a threshold beyond which patient motion is seriously problematic. As initially delivered, our 3.0T scanner was unable to meet these requirements, prompting us to develop and evaluate these, and other, clinical applications.

Methods
All studies were performed on a 3.0T VH/i (GE Medical Systems) equipped with an actively shielded Magnex 3T-94 (Magnex Scientific Ltd.) magnet. This system is equipped with a 55cm patient aperture, 40 mT/m, 150 T/m/s gradients, and a transmit-receive head coil. It also has a higher order resistive shim set (z^2, z^3, xy, xz, yz, and x^2-y^2), although the autoshim software required to calibrate the shims on a per-patient basis was not yet installed during this initial trial period. Calorimetric experiments were performed to calibrate the power monitor trip point so that the FDA's non-significant risk guidelines for SAR were adhered to. These calorimetric measurements allowed us to accurately account for the incomplete coupling efficiency between the head coil and the patient. All exams were performed with Institutional Review Board approval.

Results
With comparable-geometry 28cm-diameter birdcage coils, we measured that S/N was 2.18 ± 0.05 times higher at 3.0T compared to 1.5T. During 15 working days between 19 October and 10 November 1999, a total of 119 patients were scanned. Each scanning day lasted approximately 9 hours. All exams were checked by a Radiologist for image quality and completeness before the patient left the scanning table.

The routine brain exam included a 2.5-3 minute T1-weighted sagittal spin echo series comprising 20 5mm skip 1mm sections, a 7.5 minute high-resolution (320x256) axial oblique T2-weighted series (with proton density first echo) comprising 20 5mm skip 0.5mm sections, and a 6.5-7 minute axial oblique FLAIR series comprising 30 contiguous 5mm sections.

All 119 patient exams included the three anatomical brain series. Approximately 30% of the patients received gadolinium, with a post-contrast T1-weighted series performed in the oblique axial and coronal planes. Approximately 20% also included an MRA series, and approximately 20% included a diffusion series. All exams were considered to be of diagnostic quality. One patient was re-imaged at 1.5T because a flow artifact simulated a mass in an enlarged empty sella on a T2-weighted image.

Discussion and Conclusion
Because of our relative inexperience with the safety of implanted medical devices at 3.0T, patients with any implanted device that might even partially deflect at 1.5T were excluded from being imaged at 3.0T. Patients with non-magnetic (but possibly electrically conductive) implants were scanned only if the implant was located inferior to the clavicle, so that it would not be heated by the RF field of the head coil.

The T2-weighted and MRA sequences consistently provided higher spatial resolution than typically obtainable at 1.5T. Flow artifacts from CSF and vessels, however, were more apparent at 3.0T. In addition to being a powerful research tool, a 3.0T MRI scanner can be a capable clinical imager if the proper pulse sequences and protocols are developed.

References
1. http://www.magnex.com/
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