Physiological Limits of MRI

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Introduction

Prior to the discovery of high field type 2 superconductivity in the mid-20th century [1] there was no practical means of generating steady magnetic fields on the order of one tesla over a volume as large as an entire human body. Consequently, there has been no opportunity for evolutionary adaptation to magnetic fields of this strength and there was little information regarding the safety of human exposure to intense magnetic fields in the early 1980s when clinical MRI was introduced on a large scale [2]. Most of the available information at that time resulted from limited, informal studies of exposure to magnets utilized in high-energy physics laboratories [3]. Nonetheless, since approximately 1982, on the order of 200,000,000 clinical MR scans have been performed and, except for issues associated with the presence of magnetic foreign bodies (put in place by trauma or by surgical intervention) or the inadvertent scanning of patients with implanted pacemakers or similar devices, there is little or no evidence for any significant pathology associated with the action of the static magnetic field [4]. The very high degree of patient safety in strong magnetic fields is attributed to the extremely low value of the magnetic susceptibility and the lack of ferromagnetic components in these tissues [5].

Possible Limiting Physical Effects of Strong Magnetic Fields

Evidence has been presented for the safety of whole-body MR scanning up to 8 T [6]. However, there are several physical effects, too small to be hazardous at currently available field strengths that may eventually become significant as stronger magnetic fields become available for human imaging. These effects include the following:

- Magnetic forces drawing relatively paramagnetic tissue components into strong field regions [7].
- Magnetic torques on tissue components with anisotropic susceptibilities [8].
- Flow or motion-induced currents causing extraneous nerve or muscle excitation [9].
- Alterations in the rate of chemical reactions [10].
- Magnetohydrodynamic forces and pressures [11].
- Sensory effects such as nausea, vertigo and magnetophosphenes [12].

Theoretical analyses and animal studies in small bore, high field magnets indicate that, if patient motion in the field is limited to low velocities, it is likely that normal humans will tolerate static magnetic fields susbstantially larger than those of the largest whole body magnets (9.4 - 12 T) currently planned for human MRI.

References

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