High Field MRI: What Are the Special Safety Risks at Higher Fields?

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Target Audience: Scientists and clinicians with an interest in MR safety

Summary: The elevated internal and external static magnetic fields and higher radio frequency of MR scanners operating at high magnetic field raised some special safety risks, which must be considered when operating and installing high field scanners.

Introduction: High field MRI (>3T) offers many opportunities in clinical practice and biomedical research. However it also poses some definite risks to patients or volunteers and to staff, that can be minimized by careful management. High field MRI can involve exposing staff and volunteers to static fields greater than the exposure limits that have been recommended by international bodies in order to avoid potential, currently ill-defined hazards to health. The issues requiring special consideration at high field mainly relate to the static magnetic field, although RF heating also becomes a more serious issue.

Static Magnetic Fields: There are a variety of potential mechanisms for interaction between the human body and strong, static or slowly varying magnetic fields, including those based upon magnetic induction, magneto-mechanical effects and electron spin interactions [1, 2]. However, to date none of these have been shown to have clinically significant, long-term or short-term, deleterious effects at currently accessible field strengths. The most significant observed interaction is the 'vertigo effect' [3], which is thought to be due to interaction between the magnetic field, and the vestibular system of the inner ear [4] that is responsible for balance. To avoid inducing vertigo, subjects must be moved slowly into high field magnets. Although most people do not find the vertigo effect to be more than a minor nuisance, it can limit the tolerable working time inside the bore of high field magnets.

The International Commission for Non-Ionizing Radiation Protection (ICNIRP) currently suggest a limit of 2 T for occupational exposure to static magnetic fields in general workplaces, although for specific work applications, when the environment is controlled and appropriate work practices are implemented, exposure up to 8 T is acceptable [2]. 8 T is also the upper limit suggested by ICNIRP for patient imaging in controlled operating mode, though higher field studies in experimental mode may be carried out under IRB approval with appropriate clinical monitoring [5]. There is still relatively little data available on which the regulatory bodies can base guidelines. Groups working in high field MRI should actively consider publishing safety studies [6].

Siting issues: Fields in excess of 5 Gauss (0.5 mT) occur at an axial distance of around 20 m from an unshielded 7 T magnet, leading to an unfeasibly large space requirement in siting. Early 7 T systems thus required passive iron shielding (usually in the form of a 200-400 tonne iron box around the magnet), but this arrangement has been largely superseded by the availability of actively shielded 7 T magnets. In planning the siting of a high field system, safety in the event of a quench is an important consideration, since high field magnets generally hold a large volume of cryogenic gases.

Gradient and RF Fields: The forces experienced by gradient coil windings during MR scanning increase with increasing operating field, potentially leading to the generation of louder acoustic noise in and around high field scanners. Greater attention therefore needs to be paid to acoustic damping and gradient coil mounting in high field scanners. RF power deposition increases with field strength and at high field the RF power deposition becomes less uniform, leading to local SAR hotspots [7]. The reduction of the wavelength of the RF used in high field MRI means that interactions with implants and devices must be specifically analysed before they are used in high field scanners [8].

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