

## Magnetic Resonance Imaging (MRI)

MRI is used to distinguish pathologic tissue (such as a brain tumour) from normal tissue. MRI provides reasonable resolution with good contrast resolution (the ability to distinguish the differences between two similar but not identical tissues). The basis of this ability is the complex library of pulse sequences that the modern medical MRI scanner includes, each of which is optimized to provide image contrast based on the chemical sensitivity of MRI.

### Contrast enhancement

A contrast agent may be used to show particular areas of concern to the consultant and the team. Most commonly, a paramagnetic contrast agent (usually a gadolinium compound) is given. There have been concerns raised regarding the toxicity of gadolinium-based contrast agents and their impact on persons with impaired kidney function (Issa [2008](#), Stratta [2008](#)). More recently, superparamagnetic contrast agents (e.g. iron oxide nanoparticles) have become available, and may be used for liver imaging.

### MRI vs CT

A computed tomography (CT) scanner uses X-rays to acquire its images, making it a good tool for examining tissue composed of elements of a relatively higher atomic number than the tissue surrounding them, such as bone and calcifications (calcium based) within the body (carbon based flesh), or of structures (vessels, bowel). MRI, on the other hand, uses radio frequency signals to acquire its images and is best suited for non-calcified tissue.

MRI scanners can generate multiple two-dimensional cross-sections (slices) of tissue and three-dimensional reconstructions. MRI has a long list of properties that may be used to generate image contrast. By variation of scanning parameters, tissue contrast can be altered and enhanced in various ways to detect different features.

MRI can generate cross-sectional images in any plane (including oblique planes).

For purposes of tumour detection and identification, MRI is generally superior. However, CT usually is more widely available, faster, much less expensive, and may be less likely to require the person to be sedated or anaesthetized.

MRI is also best suited for cases when a patient is to undergo the exam several times successively in the short term, because, unlike CT, it does not expose the patient to the hazards of ionizing radiation. CT scans give a significantly higher dose of radiation (between 40 and 100 times higher) than a conventional x-ray examination. We do not generally recommend CT scans for children (Shah & Platt [2008](#), Iakovou [2008](#)) unless there is no suitable clinical alternative.

### The European Physical Agents Directive

The European Physical Agents (Electromagnetic Fields) Directive has been adopted in European legislature. By April 2008 each individual state within the European Union should have included this directive in its own law. However, it became apparent that this would cause restrictions in the use of MRI scanners and legislation has been delayed until April 30<sup>th</sup> 2012.

The directive applies to occupational exposure to electromagnetic fields (not patient exposure) and was intended to limit workers' acute exposure to strong electromagnetic fields. However, the regulations impact significantly on MRI, with separate sections of the regulations limiting exposure to static magnetic fields, changing magnetic fields and radio frequency energy. Field strength limits are given which may not be exceeded for any period of time. An employer may commit a criminal offence by allowing a worker to exceed an exposure limit if that is how the Directive is implemented in a particular Member State.

The Directive is based on the international consensus of established effects of exposure to electromagnetic fields, and in particular the advice of the European Commissions' advisor, the International Commission on Non-Ionizing Radiation Protection (ICNIRP). The aims of the Directive, and the ICNIRP guidelines upon which it is based, are to prevent exposure to potentially harmful fields. The actual limits in the Directive are very similar to the limits advised by the Institute of Electrical and Electronics Engineers, with the exception of the frequencies produced by the gradient coils, where the IEEE limits are significantly higher.

Many Member States of the EU already have either specific EMF regulations or (as in the UK) a general requirement under workplace health and safety legislation to protect workers against electromagnetic fields. In almost all cases the existing regulations are aligned with the ICNIRP limits so that the Directive should, in theory, have little impact on any employer already meeting their legal responsibilities.

The introduction of the Directive has brought to light an existing potential issue with occupational exposures to MRI fields. There is at present very little data on the number or types of MRI practice that might lead to exposures in excess of the levels of the Directive. There is a justifiable concern amongst MRI practitioners that if the Directive were to be enforced more vigorously than existing legislation, the use of MRI might be restricted, or working practices of MRI personnel might have to change. In a study by Karpowicz (2011), it is suggested that changes in procedure and organisation would enable exposure levels to remain within the current occupational guidelines. In 2010, Ng suggested that there are still safety issues needing addressing, with respect to static and time-varying magnetic fields, and radiofrequency fields. This work has come from the University of Malaya, where safety guidelines may not be as explicit, or as well monitored as in the European Directive.

Franco (2010) reported that according to the European Directive 2004/40/EC (Official Journal of the European Union, Luxembourg), employers must ensure that health surveillance is carried out to prevent adverse health effects in static magnetic field (SMF)-exposed workers. However, they continue; *"the decision-making process aiming at the provision of evidence-based health surveillance to SMF-exposed workers is characterized by controversial ethical costs and ethical benefits for workers and other stakeholders"*.

In the initial draft a limit of static field strength to 2 tesla (T) was given. This has since been removed from the regulations, and whilst it is unlikely to be restored, as it did not have a strong justification, some restriction on static fields may be reintroduced after the matter has been considered more fully by ICNIRP. The effect of such a limit might be to restrict the installation, operation and maintenance of MRI scanners with magnets of 2 T and stronger. As the increase in field strength has been instrumental in developing higher resolution and higher performance scanners, this would be a significant step back. This is why it is unlikely to happen without strong justification.

Individual government agencies and the European Commission have now formed a working group to examine the implications on MRI and to try to address the issue of occupational exposures to electromagnetic fields from MRI.

## Research

Bradley (2007), Riches (2007) and Crozier (2007, 2007) found that staff, especially when moving quickly, were exposed to time-varying magnetic field exposures which exceeded the limits stated in the published guidance. Riches concluded that the Directive will have a major impact on the current use and future development of MRI due to limitations on exposure to time-varying gradient fields and movement within the spatially-varying static field. The team believes that it will make interventional work impossible and routine MRI use impracticable in Europe.

A review of current research on staff exposure to static magnetic fields and health effects was undertaken by Franco (2008). The effects listed were vertigo, nausea and a metallic taste in the mouth, changes in blood pressure and heart rate, induction of ectopic heart beats and increased likelihood of reversible arrhythmia and a decrease of working memory and eye-hand co-ordination. It was felt that these effects may result in a possible negative influence on the performance of workers during critical procedures.

Solin (2010) concluded that there is no consistent evidence that a pre-operative breast MRI confers a benefit to the patient by improving clinical outcomes or surgical procedures. In fact, adding pre-operative breast MRI was felt to alter clinical management in ways that are potentially harmful to patients, for example, increased ipsilateral mastectomies, increased contralateral prophylactic mastectomies, increased work-ups, and delay to definitive surgery. The routine use of pre-operative breast MRI is not warranted for the typical patient with a newly diagnosed early stage breast cancer.

## Individual experiences of reactions

One man developed skin sensitivity as a result of an MRI scan, without a contrast agent. Within 24 hours he experienced a burning sensation over his back and saw skin abnormalities. He now believes the MRI damaged the nerve fibres in his skin, resulting in neuropathic pain. This 'allergic' response continues one year on.

## References

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