

Powerfrequency EMFs and Health Risks

This article is separated into 12 sections, each of which can be individually downloaded. It is a 'work in progress' incorporating new information whenever time permits.

Section 5

MRI

11. Positive health effects; apoptosis; cancer treatment; cell survival and differentiation; wound healing

12. References – 937 references

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). Another paper (Cho 2014) suggested that gadolinium induces DNA damage and apoptic cell death in human lymphocytes and that ELF-EMF enhances the cytotoxicity and genotoxicity of gadolinium.

Gadolinium MRI at any time during pregnancy was associated with an increased risk of a broad set of rheumatological, inflammatory, or infiltrative skin conditions and for stillbirth or neonatal death (Ray 2016).

More recently, superparamagnetic contrast agents (e.g. iron oxide nanoparticles) have become available, and may be used for liver imaging.

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.

One person had an MRI scan on their knee in January, which started a prolonged asthma attack.

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. In 2006, about 6 million CT scans were performed on children. An abdominal scan in a 1-year-old child results in a life-time mortality risk of about one in a thousand. While the risk to the individual is small and acceptable when the scan is clinically justified, even a small risk when multiplied by an increasingly large number is likely to produce a significant health concern (Hall 2008).

Cardiac scan

Simi (2008) found micronuclei induction and recovery up to 120h in circulating lymphocytes of individuals after cardiac scan. However, after 24 hours, the frequency returned to the control value when the exposure was within diagnostic dosage.

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 (Leitgeb & Gombotz 2012), now until October 2013 (Alberich Bayarri 2013).

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.

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"*.

A study by Gobba (2012) suggested that female MRI operators with implanted metallic IUDs should be included in the group of 'workers at particular risk' after 3 operators developed menometrorrhagia some months after an increase of the working time in an MRI unit.

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.

The highest static field exposure recorded was observed on the hand, followed by the head and the chest (Bonello & Sammut 2017). The overall maximum exposure (1479.40 mT) recorded was observed on the hand during a change of coil. It was also observed that the recorded exposure of experienced radiographers working in the MRI environment was less than that of junior staff due to different practices. This study is of significant importance in Malta since it is the first conducted in a MRI environment, especially because the results were compared with limits imposed by EU Directive 2013/35/EU.

Research

Patient

Metallic implants may cause serious tissue heating during MR imaging (Acikel & Atalar 2011). For patients wearing hearing implants with an implantable magnet the indications for MRI in devices with MRI certification should be rigorously restricted. Possible defects/dislocation of the implants may occur and the quality of the skull MRI images is reduced (Nospes 2013).

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.

Lee JW (2011) observed a significant increase in the frequency of single-strand DNA breaks following exposure to a 3T MRI. In addition, the team found that the frequency of both chromosome aberrations and micronuclei in exposed cells increased in a time-dependent manner.

Ayyıldız (2013) found that patients with fixed partial dentures (single crown or bridge) fabricated from Co-Cr, Ni-Cr, and zirconia substructures may safely undergo MRI at up to 3T. The temperatures of orthodontic brackets and wires were within acceptable ranges, to a maximum of 3°C increase, however, NiTi and stainless steel wires presented great interactions, and it was suggested that it would be safe to replace the wires before MR imaging (Gorgulu 2014).

Mortazavi (2008, 2014) found that MRI radiation significantly released mercury from dental amalgam restoration. A further study by Mortazavi & Mortazavi (2015) reported that increased mercury release after exposure to electromagnetic fields may be risky for pregnant women. As a strong positive correlation between maternal and cord blood mercury levels has been found in some studies, their findings regarding the effect of exposure to electromagnetic fields on the release of mercury from dental amalgam fillings lead them to conclude that pregnant women with dental amalgam fillings should limit their exposure to electromagnetic fields to prevent toxic effects of mercury in their foetuses.

Møllerløkken (2012) found no difference in male reproduction hormone levels immediately after, or after 11 days, following an MRI scan. Zaun (2013) found no effect on the offspring of mice exposed in utero. However, they did find a reduced placental weight of offspring of intrauterine exposed female mice that correlated with a decrease in embryonic weight in those animals exposed at the strongest magnetic field. Zahedi (2014) found that exposure to strong magnetic fields during pregnancy in mice had no deleterious effect on offspring; however, a developmental retardation could be observed postnatally with regard to weight gain and eye opening.

Van Nierop (2012, 2014) found that neurocognitive functioning is changed when exposed to movement-induced time-varying magnetic fields within a static magnetic stray field of a 7 Tesla MRI scanner. Effects include attention/concentration, visual acuity and visuospatial orientation and decreased verbal memory performance.

Women experienced dizziness more than men in higher static magnetic fields as a result of MRI exposure. It is unclear what the implications of this might be (Heinrich 2014).

Active RFID tags can affect MRI imaging quality, and it is not always appropriate for some types of MRI to be used with people wearing RFID tags (Fei 2014).

Occupational

A study by Cretti & Gambirasio (2015) found wide variations of occupational exposure parameters according to the worker's job, type of procedure and patient's state, though the regulatory limits were observed in all cases. They concluded that compliance with exposure limits prescribed by Italian law will also be met with the new 3 T MR.

Hansson Mild (2013) commented on the fact that about 100,000 workers from different disciplines such as radiographers, nurses, anaesthetists, technicians, engineers, etc. are exposed to substantial EMFs compared to normal background levels. The exposure is a very complex mixture of static magnetic fields, switched gradient magnetic fields and RF fields. This should be taken into account when investigating any potential health risks.

Huss (2017) reported that imaging technicians working with MRI scanners within the previous year may be at an increased risk of near accidents. Risks were higher in persons who worked with MRI more often and in those who had likely experienced higher peak exposures to static and time-varying magnetic fields.

The exposure to static magnetic fields from MRI scanners affected long-term spatial memory in rats (Maaroufi 2013).

Schaap (2016) reported that vertigo is associated with exposure to MRI-related SMF and TVMF. Associations were most evident with full-shift TWA TVMF exposure.

At the start of MRI activity, 81% of the operators reported at least one of the symptoms investigated by Zanotti (2016); after 2 months, 85% of the symptomatic operators reported the regression of one or more symptoms. In operators with high exposure (1.5 and 3 T scanners), the mean number of symptoms tended to be higher compared with those with lower exposure (1.5 T only), and the reduction after 2 months was significantly greater. In the whole group, occupational stress was significantly correlated with the total number of symptoms and to some of the symptoms more specifically. As stress did not differ between highly- and lowly- exposed, there is no reason to assume an influence on the observed differences in the prevalence and reduction of symptoms.