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Contents

1. Rationale
2. Defining areas of responsibility
3. Professional responsibilities
4. Staffing of MR units
5. Static magnetic field B_0
6. Time-varying (gradient) magnetic fields
7. Radio-frequency radiation
8. Cryogen hazards
9. MR phantoms
10. Implantable medical and non-medical objects
11. Pregnancy
12. Considerations for high field strength scanners (3T and above)
13. Contrast agents and other drugs
14. Manual handling in MRI
15. Fire and emergency safety and training
16. European Union Physical Agents Directive (EUPAD) - Electromagnetic fields
17. Design and planning of MR units
18. Further resources
19. References

1. Rationale

1.1 This guidance and advice document overviews safety issues in Magnetic Resonance Imaging (MRI) and, while not claiming to be all-inclusive, it provides direction to radiographic staff on where appropriate information can be found. All members of the workforce who are working, or intending to work, in MRI are recommended to read the literature listed in this document to gain a more in depth appreciation of the issues involved.

1.2 Purpose

The purpose of this document is to:

- increase awareness and reiterate safety issues which are uniquely associated with MRI
- identify the professional responsibilities in ensuring safe practice in MRI
- offer practical advice for the development of an MR safety framework
- inform departments regarding the European Union Physical Agents Directive (EUPAD)¹ concerning worker protection in electromagnetic fields (EMFs).

1.3 In this document considerations are given to areas relating to hazards, safety, good practice and professional responsibilities. It is not comprehensive as other documents are available, but is designed to be a practical reference guide and pointer in order for radiographic staff to be able to find and access information in busy MR units.

1.4 The Society and College of Radiographers (SCoR) and the British Association of Magnetic Resonance Radiographers (BAMRR) recommend that all departments have an up to date copy of the following Medicines and Healthcare products Regulatory Agency (MHRA) publication:

*Safety Guidelines for Magnetic Resonance Equipment in Clinical Use.*²

<https://www.gov.uk/government/publications/safety-guidelines-for-magnetic-resonance-imaging-equipment-in-clinical-use>

1.5 This guidance updates and replaces the previous guidance document produced by SCoR and BAMRR 2013.³ SCoR is grateful to members of the SCoR Magnetic Resonance Advisory Group (MRAG) and the BAMRR policy board who contributed to the writing of this document.

Note: *The term ‘MR operator’ in this document relates to the scanning radiographer (registered practitioner) as SCoR defines the scope of practice of assistant practitioners in MRI as being related to assisting the registered healthcare professional and to aspects of patient care.*⁴

2. Defining areas of responsibility

Further details on the following roles and the required knowledge and training can be found in Safety Guidelines for Magnetic Resonance Equipment in Clinical Use.²

2.1 Responsible person

The MR responsible person:

- has day to day responsibility for safety in the MRI centre

- is required to have sufficient MR clinical expertise and safety knowledge (or experience relevant to the nature of the department eg research scanning) to ensure that appropriate levels of MR safety and training are delivered and updated to relevant staff
- is delegated as **responsible person** by Chief Executive or General Manager
- may effectively be Clinical Director, Head of Department but more usually an Advanced Practitioner / Consultant Radiographer or practitioner in a management role in the MRI department
- should not take on the role of an **MRI safety expert**² see 2.2.
- The MHRA² advises it may be appropriate to have an MR responsible person for each MR system within an organisation.

Duties include:

- ensuring adequate written safety procedures, ethical approvals, work instructions, emergency procedures (local rules) are issued to all concerned in consultation with the MRI safety expert
- approving certification of authorized persons
- producing and issuing written safety documents ensuring that they are version controlled and regularly updated.

Note: *this is not an exhaustive list of duties; please refer to Safety Guidelines for Magnetic Resonance Equipment in Clinical Use² for further details.*

2.2 MR safety expert

The MR safety expert:

- was previously known as the MR safety advisor
- provides scientific advice to MR units
- requires expert knowledge of the physical principles of MRI and detailed knowledge of MRI techniques
- is usually a physicist registered with the HCPC.

Please refer to MHRA Safety Guidelines for Magnetic Resonance Equipment in Clinical Use² for further details on the duties of an MR safety expert.

The Institute of Physics and Engineering in Medicine (IPEM) published a policy statement⁵ outlining the role of the MR safety expert. It is the intention of IPEM that MR safety experts are accredited. A working party including representatives from SCoR, and BAMRR is currently defining the required knowledge and competencies and proposed routes of accreditation of this role.

The policy statement with further information can be viewed online at:

http://www.ipem.ac.uk/Portals/0/Documents/Publications/Policy%20Statements/IPEM_MRSafetyExpert_PolicyStatement_04102013_SK.pdf

Note: *this role could be undertaken by a suitably qualified radiographer. Further information will be issued as an addendum to this publication.*

2.3 Authorised person

The authorised person is a suitably trained member of staff authorised to have access to the MR Controlled Access area and also, depending on their role, access to the MR environment (see section 5). All authorised persons must:

- be certified by the MR responsible person when they have completed satisfactory training
- be listed on a certified list
- keep an appropriate record of their MR training. An annual screening of all authorised persons is to be kept by the responsible person
- complete and pass a screening questionnaire annually
- satisfy themselves at all times that they conform to the requirements of the screening process.

The MHRA ² defines access and supervision rights of MR authorised personnel as follows:

STAFF GROUP	MR ENVIRONMENT (Scan Room)	MR CONTROLLED ACCESS AREA outside MR environment
Authorised person Non MR environment eg Clerical staff, management staff, radiologists without formal safety training	May not enter without supervision	May enter and supervise
Authorised person MR environment eg Supporting clinical staff, junior researchers	May enter	May enter and supervise
Authorised person - supervisor eg Radiographer, researcher with appropriate training	May enter and supervise	May enter and supervise

- ⚠ Access to all other persons including patients, visitors and unauthorised staff should only be granted if accompanied by an authorised person, and following appropriate screening processes.

2.4 MR operator

The MR operator is:

- an authorised person deemed to have sufficient experience and appropriate training and is responsible for operating the scanner in a safe and appropriate manner
- responsible for the safety of patients, volunteers (and accompanying carers) who are undergoing MRI at all times
- responsible for ensuring that any equipment taken into the MR environment for the examination is suitable.

2.5 Defining categories of staff

All staff required to enter the MR controlled access area and the MR environment to carry out their duties will require training relating to the safety aspects of MRI. The level and depth of this training will differ according to the role of the staff member.

Further information on training requirements can be viewed in section 4.17.1 in Guidelines for Magnetic Resonance Equipment in Clinical Use.²

See also section 4.1.2 of this document

MHRA² has defined the following categories of staff. Please refer to MHRA guidance for further details.

Category (A): MR OPERATOR - those wishing to operate, maintain or modify the MRI equipment such as radiographers, radiologists, service engineers

Category (B): Personnel who do not fall into category (A) but are present with a volunteer or patient **during scanning** such as radiologists, anaesthetists and nurses

Category (C): All staff who are required to enter the MR ENVIRONMENT when scanning is not taking place eg dedicated cleaning staff, estate maintenance staff

Category (D): All other staff who are required to enter the MR CONTROLLED ACCESS AREA but will not enter the MR ENVIRONMENT eg clerical staff.

3. Professional responsibilities

3.1 Referrals for MRI

3.1.1 Referrals for MRI examinations should include a detailed clinical history and clearly state what examination is being requested.

3.1.2 Referral forms should be signed and dated.

3.1.3 Referring clinicians should also complete the relevant safety section on the referral form and/or submit any safety information known to them about the patient (ideally at the time of referral, in consultation with the patient). However, the person taking the patient/volunteer into the MR Environment should be certain that all departmental safety checklists have been carried out and is entirely confident that it is safe to do so.² See also section 3.2 of this document.

3.1.4 MR departments must ensure that the referral is from an authorised source.

3.2 MRI safety screening questionnaires

3.2.1 Risk/benefit decisions must be taken by the MRI team in consultation with the patient or their guardian. Before the patient is allowed to enter the MR controlled access area, a suitably trained authorised person (usually the MR operator) is responsible for ensuring that the risks are made clear and that the evidence provided is based on the most current and up to date literature.

3.2.2 Written documentation, normally in the form of a questionnaire, regarding the risk assessment for each patient should be completed by the patient, and checked through with them by a suitably trained authorised person (usually the MR operator) Any discrepancies or queries should be discussed with the patient and the decision to scan should be made in conjunction with the local rules and employing authority policies.

- 3.2.3** The questionnaire should be signed and dated by the patient and countersigned as checked by the MR operator.
- 3.2.4** There may be occasions when it is not possible for the patient to be able to answer the safety questionnaire directly, for instance, in the case of the unconscious patient, or clients who do not speak English.
- 3.2.5** In the case of the unconscious patient, close reference should be made to the patient notes and, ideally, the next of kin may be asked to complete the questionnaire. Reference should be made to employing authority policy on consent, and this should be reflected in the local rules. Please also refer to 3.3.1. Any doubt about patient status with regard to MR safety should be rigorously pursued; this may involve, for example, plain radiography to establish metallic intra-orbital foreign body (IOFB).
- 3.2.6** Patients who do not speak English as a first language should be accorded the same information and confidentiality as any other patient. Ideally, an employing authority translation service, using an approved translator, should be utilised. This should ensure that the questions put to the patient, and the answers received, are accurate and not changed. A translator may be booked in advance, or a phone translation service, approved by the employing authority should be utilised. If the translator is present they should sign the form to confirm that they asked the patient all the questions listed, and that the answers noted are a true record of those received. If the translator is not present, a note of their name or identification code should be made on the form. The safety of the patient, however, is the responsibility of the MR operator. It should not be common practice to use a relative for translation purposes, and it is inappropriate for minors to perform this function.

3.3 Consent

3.3.1 Duties

As a registrant with the Health and Care Professions Council (HCPC) it is a requirement to obtain consent from service users or other appropriate authority before providing care, treatment or other services.⁶ Radiographers undertaking a clinical imaging diagnostic exam have a duty of care to ensure that patients are fully aware of the procedure and have consented to it. The health professional carrying out the procedure is ultimately responsible for ensuring that the patient is genuinely consenting to what is being done: it is they who will be held responsible in law if this is challenged later.⁷

3.3.2 Consent and adults with impaired capacity

The SCoR advises that all reasonable steps must be taken to support a patient to make a decision. This involves taking extra time with the patient and using language appropriate to the level of understanding.⁷

The patient's carers may be able to help in this regard, but they cannot give valid consent on behalf of the patient, including the patient who lacks capacity. Acting in the best interests of the patient may involve the radiographer delaying or postponing the procedure if, in their opinion, more time needs to be taken to obtain consent.⁸ The referrer should be informed and discussions may include possible alternative procedures, if relevant.

If the employing authority has policies regarding consent which have been developed locally,

these policies should be followed. If, after taking every practical step to achieve consent from the patient, consent is not achievable, the radiographer needs to be clear that, by providing imaging and/or treatment, they are acting in the best interests of the patient.

Radiographers must record decisions taken along with a brief explanation of why the decisions were taken.

3.3.4 Consent and the child

Consent for MR scanning in the case of minors should reflect employing authority policy.

3.3.5 Further information and advice on consent is published by SCoR.^{7,8,9}

3.4 Decision to scan

3.4.1 There may be occasions where MRI is requested for patients with implants who are at particular risk such as:

- those with implants where MRI is contraindicated. *See also section 10.3*
- when there is insufficient evidence from the implant manufacturer that MRI is safe to perform
- the conditions for safe scanning of an implant cannot be met.

3.4.2 The decision to scan these patients should be made on a case by case basis, and following a risk assessment and risk benefit analysis. While essential that the referring clinician, patient and reporting clinician are instrumental in this; the decision should be made in consultation with all members involved in the process. This should include for example the MR safety expert, MR responsible person, and the MR operator.

3.4.3 The process for dealing with such patients should be clearly documented within the local rules.

3.4.4 The radiographer performing the scan should be satisfied that:

- alternative imaging procedures have been considered
- the patient is fully aware of what they are consenting to
- a full risk assessment and risk benefit analysis has been carried out in accordance with the process set out in the local rules
- by proceeding with the scan, they are acting in the best interests of the patient
- the decision to scan is clearly documented.

3.5 Reporting of incidents and near misses

All incidents and near misses related to patient or staff safety within the MR unit must be reported in accordance with local employers' rules. Incidents and near misses involving MR diagnostic equipment should also be reported: this includes burns and overheating, projectile incidents and contrast injector failures.

A full list detailing what should be reported is available in Appendix 4 of the MHRA Guidance Document.² Incident forms and online reporting available from:

<https://www.gov.uk/report-problem-medicine-medical-device>

The above webpage also provides links for the reporting of incidents in Scotland, Wales and Northern Ireland.

For any queries contact the Adverse Incident Centre: aic@mhra.gsi.gov.uk

3.6 Knowledge, skills and competency

The science of MRI and technological developments in equipment and device implants evolves rapidly and radiographers must ensure that their knowledge, skills and competencies keep pace with these advances in order to ensure a quality and safe service.

The increase in the scope of MRI applications means that radiographers have extended their roles to incorporate advanced techniques.¹⁰

It is a requirement as a registered healthcare professional to ensure that knowledge and skills are kept up to date and that they act within the limits of their knowledge, skills and experience.⁶

3.6.1 Scope of practice

In identifying and communicating their individual scope of practice, radiographers must consider the roles and the environments in which they work and ensure that they are educated and competent to operate in their specific roles.¹¹

Further information is available in the SCoR publication *The Scope of Practice*.¹¹

4. Staffing of MR units

The SCoR receives many enquiries regarding the staffing of MR units, primarily relating to the suitable skill mix and minimum staffing levels. Generally, SCoR tends not to be prescriptive about staffing levels as configurations will very much vary to meet local circumstances and service delivery model; rather we would suggest an approach that considers certain principles in order to provide a quality, safe and effective service for patients and staff.¹²

Under the Health and Safety at Work Act,¹³ employers have a general duty to ensure the health, safety and welfare at work of all employees. Employers are also obliged to carry out risk assessments into all aspects of working including systems and patterns of work. When considering the staffing requirements of an MR unit, managers should take into account the following:

4.1 Safety of patients and staff

Patient safety is paramount. There are particular safety issues associated with MRI: strong magnetic fields, time varying magnetic fields and radio frequency pulses. Staffing levels and competencies should be such that there are no compromises to patient safety. Staffing levels should take account of the fact that MR operators must maintain visual and audio contact with the patient throughout the scan and should not leave the control room during the scan unless it is to enter the scan room.²

The MRI safety screening questionnaire is an essential component in ensuring patient safety. Staffing levels should take account of this process.

4.1.1 Lone working

The MHRA advises that staff should not work alone, especially out of hours. Where it is considered essential that staff do work alone, the Lone Worker policy of the Trust should be considered.²

The Health and Safety Executive (HSE) advises: *‘Risk assessment should help employers decide on the right level of supervision. There are some high-risk activities where at least one other person may need to be present. Examples include: working in the health and social care sector dealing with unpredictable client behaviour and situations.’*¹⁴

4.1.2 MR safety training

Many categories of staff are required to have contact with the MR unit during the course of their duties. It is essential that these staff receive a level of training in the hazards associated with MRI appropriate to their role. The MHRA² defines what that training should consist of using the categorisation of staff as defined in section 2.5 of this document.

Further information on training requirements can be viewed in section 4.17.1 of the MHRA Guidance Document.²

4.1.3 MRI safety knowledge

SCoR and BAMRR have recommended that all staff working in a clinical or clinical support role in MR units should have as a minimum:

- knowledge and understanding of the threats posed by the static magnetic field
- understanding of the MR controlled access area and MR environment
- awareness of MR authorised personnel
- understanding of the screening process and access rights
- emergency procedures within the MR environment
- understanding of the nature of a magnet quench and when a system may need to be quenched by the operator
- understanding the labelling system for MR equipment
- understanding the requirement for hearing protection and correct positioning
- understanding the correct use and positioning of the coils and cables and ancillary equipment.

Radiographers require further post-registration knowledge and understanding in the following areas:

- bio effects of the static magnetic field
- projectile and attractive forces
- bio effects of time varying gradient magnetic fields
- bio effects of RF radiation
- recommended exposure value limits
- sequence selection and parameter manipulation to minimise all of the above
- conditional implants and devices
- contrast agents and other drugs.

4.1.4 All staff should have adequate training in departmental emergency procedures

4.1.5 When considering staffing using a radiographer working alongside a non- clinically trained helper then provision must be made for adequate rest periods for the radiographer, this would

include a review of the bookings and case type .The helper must be suitably trained as indicated above and authorised by the MR Responsible person

4.2 Equitable service provision

Managers should consider if the service being offered is of the same quality and safety for the patients and staff throughout the whole day ie will there be any difference in the service delivered to a patient attending at 9am than one attending at 9pm?

4.3 Skills, experience and knowledge of staff

When considering staffing using radiographers working with either a non-clinical helper or an assistant practitioner grade then the radiographer should be appropriately experienced:

- with post registration skills and knowledge in MRI
- with skills in clinical decision making eg appropriate actions for incidental findings
- in taking responsibility for the episode of care, particularly in the absence of other staff trained in MRI.

4.4 Assistant practitioners in MR units

The role of an assistant practitioner in MRI is related to providing support for other registered healthcare practitioners eg radiographers and radiologists, and for aspects of patient care.⁴

5. Static magnetic field (B_0)

5.1 Definition

Static magnetic field (B_0) is dependent on the field strength of the magnet.

The SI unit used for measuring magnetic field strength is the tesla, its symbol is T. An alternative unit of measurement is the Gauss. 1tesla is equal to 10,000 Gauss.

A magnetic field of one tesla (1T) is approximately 30,000 times as powerful as the Earth's magnetic field.

5.1 MR controlled access area

Please refer to the MHRA Guidance Document² page 24 for an example layout of an MRI Unit.

An MR controlled access area is characterised by the MHRA as follows: *A locally defined area of such a size to contain the MR environment. Access to this area should be restricted and controlled by suitable control methods (eg keypad entry) with suitable warning signs displayed at all entrances.*²

5.2 MR environment

The MR environment is defined by the MHRA as *'the three dimensional volume of space surrounding the MR magnet that contains both the Faraday shielded volume and the 0.5MT field contour (5 Gauss (G) line). This volume is the region in which an item might pose a hazard from exposure to the electromagnetic fields produced by the MR equipment and*

accessories'.² **Note:** the MR environment can include aspects of the technical room and console area

- ⚠ Owing to the hazards of the static magnetic field described in this section, resuscitation of patients should take place outside the MR environment. Local rules should outline specific procedures to reflect this.

5.3 Fringe field

Every MR scanner has an affiliated fringe field. The extent of this fringe field is dependent upon the static magnetic field strength (B_0), type of shielding (active, passive cladding or whole room shielding) and whether the magnet has an open or closed design.

- ⚠ Fringe field plot diagrams should be displayed in every MR control room highlighting the 0.5mT (5 Gauss line) and the 3mT (30 Gauss line).

5.4 Projectile zone

Some MR units, for example those performing interventional MRI, may wish to define a projectile zone within the MR environment.

A projectile zone is '*a locally defined volume containing the full extent of the 3 mT magnetic field contour, or other appropriate measure, around the MRI scanner.*'²

5.5 Biological effects

The interaction of the static magnetic field (B_0) with the body and its functions may result in the creation of electrical potentials, currents generated by body movements and the possible displacement of naturally generated currents within the body by (B_0). Electrical potentials and related effects during physical movements within static magnetic field gradients may induce sensations of vertigo, nausea, phosphenes and a metallic taste in the mouth. Public Health England, PHE, (formerly The Health Protection Agency HPA)¹⁵ offers the following advice regarding the movement of patients and volunteers in the static field:

- ⚠ '*The biological effects most likely to occur are the production of vertigo-like sensations and these acute effects are associated with movement in the static field. The sensitivity to these effects varies considerably between individuals. Patients and volunteers should be moved slowly into the scanner, to avoid the possibility of vertigo and nausea.*'

Further recommendations guidance and exposure limits relating to bioeffects of B_0 can be viewed in the following publications:

Public Health England *MRI Procedures: Protection of Patients and Volunteers 2008*¹⁵
<https://www.gov.uk/government/publications/magnetic-resonance-imaging-mri-protecting-patients>

International Commission on Non- Ionising Radiation (ICNIRP) *Guidelines on Limits of Exposure to Static Magnetic Fields 2009*¹⁶
<http://www.icnirp.org/cms/upload/publications/ICNIRPstatgdl.pdf>

*Amendment to the ICNIRP 'Statement on Medical Magnetic Resonance (MR) Procedures Protection of Patients' 2009*¹⁷

5.6 Projectile and attractive forces

The potential hazard of the projectile effect of ferro-magnetic material in a strong magnetic field must be taken very seriously. The HPA reports that serious incidents have occurred including a patient fatality when items such as ferromagnetic oxygen cylinders have inadvertently been brought into the scan room.¹⁵

- ⚠ **Extreme caution must be employed, and strict screening protocols in place and adhered to, to ensure ferromagnetic items do not enter the MR environment. Loose metallic objects can reach considerable velocities.**

5.7 Labelling of equipment

All equipment used or stored within the MR environment should be clearly labelled as one of the following as defined by the American Society for Testing and Materials.¹⁸



MR safe – defined as ‘an item that poses no known hazards resulting from exposure to any MR environment. MR safe items are composed of materials that are electrically nonconductive, non metallic, and nonmagnetic’

MR conditional – defined as ‘an item with demonstrated safety in the MR environment within defined conditions. At a minimum, address the conditions of the static magnetic field, the switched gradient magnetic field and the radiofrequency fields. Additional conditions, including specific configurations of the item, may be required.’

MHRA further advises:

*Descriptions of **MR CONDITIONAL** should specify information such as the maximum magnetic field in which the device was tested, the magnitude and location of the maximum spatial gradient, the maximum rate of change of the gradient field, and radio-frequency fields tolerated in terms of RF interference, RF heating and type of transmit mode.*²

MR unsafe – defined as ‘an item which poses unacceptable risks to the patient, medical staff or other persons within the MR environment.’

- ⚠ All staff should be conversant with the labelling system and understand the conditions for use. Further information on the requirements regarding labelling of equipment can be viewed in the MHRA guidelines.²
- ⚠ Departments should take into account the different field strengths when labelling equipment. For example, if a department is equipped with two MR units of 1.5T and 3T only equipment which is safe in both units should be labelled as MR safe.
- ⚠ Clear guidance for use should be marked on equipment that is MR conditional.

5.7.1 Ancillary equipment

- ⚠ Caution should be exercised when assessing, purchasing and authorising equipment for patient support in the MR environment. Equipment must be assessed for MR compatibility and clearly labelled as indicated in section 5.7. Departments should ensure that an up to date inventory is kept of all equipment for use in the MR environment.

5.7.2 Other items

The MHRA makes the following recommendations regarding other items that may be used in the MR Unit (eg patient comfort and immobilisation aids)

*'Many items such as consumables cannot be reasonably labelled. Sites should have processes in place to ensure that these items are safe.'*²

5.8 Procurement

The MR responsible person and/or the MR safety expert should be involved in all procurement decisions relating to items for use in the MR environment.

6. Timevarying (gradient) magnetic fields (dB/dt)

6.1 Time-varying magnetic field gradients in MR systems provide position-dependent variation in magnetic field strength. The gradients are pulsed and the faster the sequence of imaging, the greater the gradients' fields change rate. The main concerns associated with time-varying magnetic fields are biological effects and acoustic noise.

6.2 Biological effects

6.2.1 Subjecting the human body to time-varying electromagnetic fields leads to induced electric fields and circulating currents in connective tissues. Induced electric currents can be sufficiently large to interfere with normal function of nerve cells and muscle fibres. An example of this is the sensation of flashes of light caused by induced currents stimulating the retina.

6.2.2 Peripheral nerve and muscle stimulation

At low frequencies, induced currents can produce stimulation of nerve and muscle cells.¹⁹ The body is most sensitive at up to about 5 KHz. Extreme cases can result in limb movement or ventricular fibrillation.

6.2.3 Implant interaction

Time-varying magnetic field gradients can interact with implants. This may result in device heating and vibration.²

- ⚠ Reference to exposure limits and relevant standards should be made and can be found in the MHRA guidelines.²

6.3 Acoustic noise

Acoustic noise caused by the gradient coils switching on and off during the scan can reach unacceptable levels. In general, the higher the field strength, the higher the acoustic noise level, but this effect is not exponential and is also dependent on pulse sequence. PHE¹⁵ reports that the threshold of instantaneous and permanent acoustic trauma normally associated

with exposure to impulsive noise is 140dB in adults – children may have a lower threshold and maximum peak levels of 120dB are advised.

- ▲ It is recommended that departments provide adequate hearing protection to **ALL** patients and others remaining in the scan room eg carers, anaesthetic staff, etc.
- ▲ Radiography staff should be trained in the selection and fitting of hearing protection.
- ▲ MR operators should be aware of noise reducing protocols and trained in their utilisation particularly for those patient groups who are sensitive.

7. Radio-Frequency radiation (B1)

7.1 Biological effects

Exposure to radio-frequency (RF) radiation results in increased oscillation of molecules and generation of heat. Dissipation of this heat occurs through the dilatation of blood vessels and increased blood flow. Avascular structures are therefore less efficient in removing this heat. RF exposure of patients is usually characterized by means of the ‘specific energy absorption rate’ (SAR), which is defined as the average energy dissipated in the body per unit of mass and time.¹⁷

The International Commission on Non-Ionizing Radiation Protection (ICNIRP) summarises: *For whole-body exposures, no adverse health effects are expected if the increase in body core temperature does not exceed 1°C. In the case of infants and persons with cardiocirculatory impairment, the temperature increase should not exceed 0.5°C. With regard to localised heating, it seems reasonable to assume that adverse effects will be avoided with a reasonable certainty if temperatures in localised regions of the head are less than 38°C, of the trunk less than 39°C, and in the limbs less than 40°C.*¹⁷

However, good practice should mean that RF deposition should be minimised in all patients. An accurate patient weight and height (if required) should be input into the system and manufacturer software will alert scanner operators to high SAR sequences.

- ▲ All patients should be weighed **prior** to scanning in accordance with manufacturers guidelines.
- ▲ The patient’s height may also need to be recorded depending on the manufacturer’s guidelines.

7.1.1 SAR Limits

SAR limits have been defined by the International Electrotechnical Commission (IEC)²⁰ and ICNIRP¹⁶. MHRA² recommends that departments make themselves familiar with the SAR limits used by their system from both the IEC standard and the manufacturer’s users manual. The use of different operating modes with regard to the varying SAR levels should be recorded within the local rules. Departments should also be aware that the IEC SAR limits are set assuming moderate environmental conditions of relative humidity and ambient temperature. There is a risk of overheating the patient if SAR is not reduced in adverse conditions ie in high ambient temperatures and high relative humidity. PHE¹⁵ recommend that departments follow the ICNIRP guidelines for RF fields for each operating mode and additionally that an upper temperature limit be specified for the experimental operating mode.

- ▲ MR operators should ensure that a good airflow is passing through the MR scanner while patients are in situ.

- ▲ MR operators should be aware of the acceptable limits of humidity and ambient temperature for each scanner.

Note: *this information should be provided within the manufacturer's literature.*

- ▲ MR operators should be aware of the different operating modes available on systems, and their importance in ensuring that SAR levels remain as low as reasonably possible. Local rules should provide clear guidance on the use of such operating modes.

7.2 Induced current burns

7.2.1 Burns will occur when patients are positioned in such a way to create a conductive loop pathway, for example where thighs meet or when hands are clasped. Poor positioning of the patient and associated leads and sensors are the cause of many burns.

7.2.2 Care should be taken to ensure that cables should be correctly positioned and avoid them touching patients. The cables should not be crossed, looped or allowed to lie diagonally across patients. Ideally cables should lie parallel and as close to the centre of the bore as possible, and should not touch the bore of the magnet at any point.

7.2.3 Patient skin should be insulated from the bore of the magnet and staff should ensure that there is no skin to skin contact. Foam pads 1-2 cm thick should be used to insulate patients from cables, the bore and between limbs.²

7.3 Contact burns

Contact burns may occur in patients where there is contact with metallic objects that act as conductors such as coils, cables, monitoring equipment, transdermal patches.

Contact burns have been reported due to metallic fibres in clothing.²¹ There is a reported case of a patient receiving a serious burn in MRI due to the paramagnetic ink in a wristband.²²

- ▲ Careful positioning technique is essential in order to avoid any skin to skin contact.
- ▲ Clothing should be checked to ensure it is safe and ideally patients changed into suitable hospital provided clothing.
- ▲ Burns from poor patient and cable positioning are entirely avoidable with good MR practice.
- ▲ Staff should visually inspect patients after imaging to look for any areas of skin redness that may develop into a burn.
- ▲ All incidents of burns should be reported as outlined in Section 3.5 of this document.
- ▲ It is recommended that patients are provided with an after care leaflet as it is possible that a burn will develop after the patient has left the department.

7.3.1 Transdermal patches

Some transdermal patches contain metal within the backing which could potentially become conductive, leading to skin burns. Heating may also pose a problem for some medicinal patches leading to an overdose due to more of the medicine being released into the skin

- ▲ Transdermal patches should be removed prior to the patient entering the scan room if they contain, or may possibly contain metal within the backing or maybe affected by heat.

- ▲ Patients should be advised to bring a spare patch. We recommend that this information is included within the patient information literature

7.3.2 Make up, piercings, tattoos

Non-medical objects such as piercings and make-up which have high iron oxide content may cause burning and, wherever possible, should be removed both for patient safety and diagnostic image quality. Some tattoos also have a high ferrous content and patients should be counselled regarding the possibility of local burns and asked to report any discomfort immediately and scanning stopped. Consideration should also be given to patients who have hair extensions as there are certain types that are bonded or tied to the hair using metal components.

8. Cryogen hazards

Cryogens should only be handled by authorised and trained cryogen suppliers.

8.1 Venting in superconducting magnets

Superconducting magnets offer a potential cryogen hazard. Adequate attention should be paid to the provision of the venting of the cryogens, including ensuring that the external vent pipes are of the correct dimensions and in the case of a quench, able to withstand pressures above that recommended by the manufacturers, as outlined in the MHRA guidelines.² External vent pipes should also be designed and fitted so that there is no ingress of rain, or other detritus and they should have a regular maintenance and inspection schedule.

- ▲ MR scanner manufacturers are not usually responsible for the maintenance of quench pipes and do not routinely check them during planned preventive maintenance.²
- ▲ Helium levels should be checked and recorded regularly in accordance with manufacturers' recommendations with mechanisms in place to report any sudden drop or low level.

8.2 Quench hazards in superconducting magnets

There should be no hazards from cryogens for MR scanning staff, visitors and patients, provided adequate attention has been paid to the provision of venting directly to the air outside the unit. In the event of a quench, low temperature liquefied gases, designed to keep the magnet close to absolute zero (-273°C) expand and boil off to the outside. In order to detect any unplanned leakage of helium into the scanner room, suitable low oxygen warning alarms should be placed in the MR room and be regularly checked and maintained. If, for any reason, the gases should enter the room instead of exiting to the outside, there will be the hazard of asphyxiation owing to the displacement of oxygen, hypothermia and frostbite. There may also be over pressurisation in the room due to the rapid expansion of the liquid gas and this may make it difficult to enter the MR room.

- ▲ If the low oxygen monitor alarms or a quench should occur, the MR environment should be evacuated immediately.
- ▲ Appropriate local emergency procedures should be in place and included in the training programme for all authorised personnel. See also section 15.
- ▲ Departments should adhere to the manufacturers' recommendations regarding maintenance

programmes and checking of equipment.

- ⚠ Departments must also ensure that a system is in place for handover of responsibility to and from engineers during maintenance checks and system repairs.

9. MR phantoms

MR phantoms are utilised in performance testing of the MR system; they are generally filled with aqueous paramagnetic solutions.

9.1 Storage and handling of phantoms

MR departments should follow the manufacturers' guidance on the storage and handling of MR phantoms. A record should be kept detailing the contents of each phantom; this record should be passed to fire departments in the event of a fire in the MR scanner. The fluid content of some MR phantoms can be toxic e nickel. Local rules should define protocols for dealing with phantom spillages in accordance with COSHH²³ regulations. Protocols for the general use of phantoms should also be stipulated in the local rules.

10. Implantable medical and non-medical objects

The use of MRI continues to expand in the UK, alongside advances in device technology. In order to ensure good patient management and patient safety, departments should implement robust procedures to ensure the MRI safety status of **any** implanted device. SCoR and BAMRR recommend that departments obtain an up to date copy of the following publication *Reference Manual for Magnetic Resonance Safety, Implants and Devices*.²⁴ This contains safety advice and guidance and a comprehensive list of implants alongside the field strength under which they have been tested. The list can also be viewed on the website www.mrisafety.com²⁵

However, as these are both American hosted publications they may not always contain information on a particular device. In this instance, contact should be made directly to the device manufacturer to ascertain its MR safety status.

- ⚠ Departments should be aware that the MR compliancy listing of an implant may be changed and should ensure that their information is kept up to date.
- ⚠ All visitors and patients should be adequately screened by means of a safety questionnaire prior to entering the MR controlled access area and no-one should be allowed to enter if there is any doubt regarding the compliancy of any implants. Please also see section 3.1
- ⚠ Departments should have a mechanism for recording and storing details obtained regarding an implant's MR compliancy.
- ⚠ For MR conditional devices departments may need to liaise with their MR safety expert and equipment manufacturer to ensure that the conditions can safely be met.
- ⚠ Radiographers should be aware of manufacturers' features that assist in meeting conditional specifications, one such example is the Philips *Scanwise* Implant technology.²⁶
- ⚠ Manufacturers provide written conditions under which a conditional implant can be scanned. It is very important for the MR operator to understand in practical terms the

conditions of the spatial magnetic field gradients of their scanners and the SAR limitations

- ⚠ MR operators should be aware that the spatial field gradient of wide bore systems can be higher than the equivalent narrow bore system. This may alter the status of the implant in wide bore systems.
- ⚠ The field strengths and other relevant operating parameters at which specific implants have been tested should be noted when assessing the safety of implants. Safety at one field strength may change at another.
- ⚠ It should be noted that many implants and devices have **NOT** been assessed at field strengths of 3T and above.
- ⚠ If there is any doubt about an implant, departments should proceed with caution. The SCoR and BAMRR recommend that written evidence regarding an implant's compliancy be obtained prior to scanning. If a department is unable to obtain the required information then scanning should not take place or should be delayed until a risk/benefit analysis and risk assessment has taken place. **See also 3.4 and 10.3**

Note: *Manufacturers of implants and devices have a duty to supply safety information. If you are unable to obtain such information, please report it to the MHRA.*

10.1 Active implanted medical devices (AIMD)

Mechanically, electrically and magnetically operated devices may malfunction in the presence of strong magnetic fields. This malfunction may not be obvious at the time of examination but may have serious consequences subsequently. Examples include:

- cardiac pacemakers
- cochlear implants
- programmable hydrocephalus shunts
- implanted neurostimulation systems
- implanted drug infusion pumps.

Note: *this is not an exhaustive list of examples.*

- ⚠ Departments should ensure that their local rules contain information about active device implants which are MR unsafe.
- ⚠ The process for scanning patients with MR conditional AIMDs should be clearly documented.

10.1.1 Cardiac pacemakers

Most cardiac pacemakers are contra-indicated in MRI. Field strengths as low as 1mT may be sufficient to cause programming changes or to close reed switches. Such patients should not enter the MR environment. Departments should also be aware of patients who have had a pacemaker removed and should check for any remaining pacemaker wires which can act as antennae and cause induced currents. However, there are now a number of manufacturers in the UK that have developed MR conditional pacemakers and leads.

10.1.2 MR conditional pacemakers

Many manufacturers have developed MR conditional pacemakers, allowing for patients with these to undergo MRI scanning under certain stated conditions for safe operation.

Some examples include:

BIOTRONIK Pro MRI Pacing systems - further information available at: http://www.biotronik.com/wps/wcm/connect/en_promri/biotronik/home/²⁷ and the

MEDTRONIC SureScan - Advisa MRI Pacemaker and Ensura MRI Pacemaker systems. Further information available at: <http://www.medtronic.com/surescan/index.html>²⁸

In addition to complying with the manufacturers' conditions for safe operation, the SCoR advises that departments formulate a local policy to be included within the local rules.

Such a policy should include: a patient pathway, clearly defined roles and responsibilities of the radiology department, the radiographic staff and the cardiology department, a list of any contraindications, potential adverse events and emergency procedures, the manufacturers' specific operating instructions and any local specific instructions.

- ⚠ This should include a mechanism for checking that both the pacemaker and the leads are MR conditional.

10.2 Non-active devices

There is a risk that implanted ferromagnetic devices will undergo attractive forces, such that they can dislodge, causing serious injury or discomfort to the person concerned. Such devices will be labelled as MR unsafe, MR conditional or MR safe. Examples include:

- coils, stents and filters
- aneurysm clips
- heart valves
- orthopaedic implants.

Note: *this is not an exhaustive list of examples.*

- ⚠ Departments should ensure that their local rules include information about non-active device implants which are MR unsafe.
- ⚠ For those that are MR conditional, a process for scanning patients with such implants should be clearly documented.

10.2.1 Aneurysm clips

Many departments take the decision not to scan patients with aneurysm clips. MHRA² advises: *Scanning must not proceed unless there is positive documented evidence that the aneurysm clip is non-ferromagnetic. For example, titanium, tantalum and vanadium are non-ferromagnetic, whereas stainless steel has varying degrees of para- and ferromagnetism.*

- ▲ If your department has a policy to scan MR conditional aneurysm clips, a clearly defined process for ensuring accurate MR compliancy details of the clip and the process for scanning these clips should be documented within the local rules.

10.2.2 Recent implants

10.2.2.1 Great care must be taken with regard to recent MR safe or MR conditional **ferromagnetic** implants or clips, which are not anchored into bone, before they become embedded with fibrous tissue. Local rules should specify the time which should elapse prior to scanning, but should not be less than six weeks.

10.2.2.2 Those objects, such as bone screws or joint replacements which are firmly anchored, may safely be scanned, but should be monitored carefully because the object may be subject to temperature rise; scanning should be discontinued if discomfort occurs. Image quality around the site will, in any case, be seriously degraded and examination may not be of diagnostic quality.

10.2.2.3 Passive implants, that is those that contain no electronic or magnetic components and are made of non-ferrous material, are safe to scan immediately at the field strength at which they were tested.²⁴

10.3 Scanning patients with implants where MRI may be contraindicated

MHRA has issued guidance relating to the scanning of patients with implants where MRI may be contraindicated. It states '*there may be a need in certain scenarios to perform an MRI exam on such a patient and advise a multi disciplinary team approach be taken with a full risk assessment*'.²

- ▲ SCoR and BAMRR advise that the risk assessment and decision to scan should be made on a case by case basis.

See also section 3.4

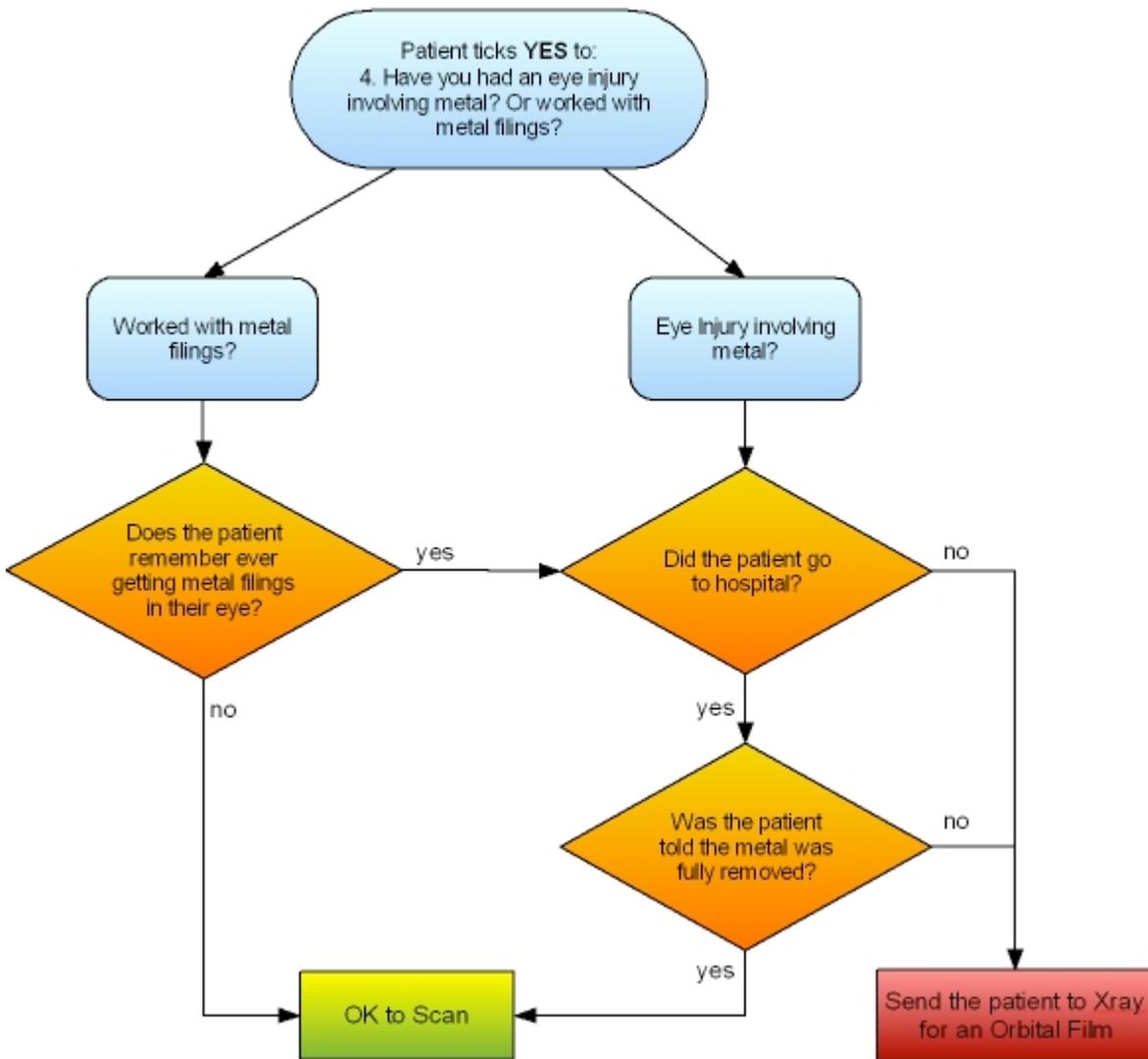
10.4 Intra orbital foreign bodies

10.4.1 Patients

Intra orbital foreign bodies (IOFB) are of particular concern and any patient, who presents with a history of an IOFB, should be treated with caution. SCoR and BAMRR recommend that departments initiate a clinical screening process. This should be documented within the local rules.

An example of such a process provided by BAMRR is described below:

Orbital Film Decision Process



Note: Referrals for orbital X- Rays should only be made by individuals entitled to act as a referrer by their employer. ²⁹

⚠ Departments should also investigate the existence of any previous orbital imaging prior to the patient undergoing an X- ray to exclude an IOFB.

10.4.2 Staff or carers accompanying a patient

Staff or carers accompanying a patient should not enter the MR environment nor should they undergo an X -Ray if they have a history of an IOFB. In such an instance the department should make alternative arrangements if the patient requires a carer within the scan- room.

10.4.3 Volunteers

Volunteers who present with a history of an IOFB should not generally be scanned (although they should be advised that this would not necessarily preclude them for a clinical

scan if they were to require one in future). However, if there has been provision made within the ethical approval for exposure to ionising radiation then the volunteer may proceed and undergo the clinical screening procedure for IOFB as outlined in 8.4.1.

10.5 Non-medical objects

10.5.1 Bullets and shrapnel

Metallic objects in the body (such as shrapnel or a bullet) become fibrosed in tissue within six weeks. Beyond that time it may be safe for scanning. However, consideration must be given to the likelihood of heating effects and also the potential for larger, ferromagnetic objects to experience significant forces whilst being positioned within the bore of the magnet.

Any large (>1 cm³) metallic fragments should be assessed on a case by case basis. Such objects are of greater concern if they are located near significant soft tissue or vascular structures. Therefore, obtaining current and previous imaging is essential in the assessment of risk versus benefit required before the MR scan may proceed. Involvement of the patient, the referring clinician and a radiologist or consultant radiographer who can review and comment on related imaging is recommended in such cases.

- ▲ Consideration should be given to utilising low SAR sequences during scanning of these patients.

11. Pregnancy

11.1 MRI of the pregnant patient

For MR procedures on pregnant women, the safety of both the mother and the developing foetus needs to be considered. There are numerous sources of guidance and readers should refer to the relevant sections of the guidance listed in 11.2

- ▲ The decision to scan should be documented in the patient's notes and scanning should usually take place in **normal mode**.

11.1.1 Scanning of the pregnant patient in controlled mode

The MHRA advises *'If the decision is taken to scan in controlled mode this should be taken following a full risk benefit analysis and made at the time by the referring clinician, consultant radiologist and patient. This decision should be recorded in the patient's notes and steps should be taken to utilise sequences that minimise RF and acoustic noise'*.²

11.2 Current guidance

ICNIRP *Guidelines on Exposure to Static Magnetic Fields 2009*¹⁶

ICNIRP *Amendment to the ICNIRP "Statement on Medical Magnetic Resonance (MR) procedures Protection of Patients" 2009*¹⁷

PHE *Protection of Patients and volunteers undergoing MRI Procedures 2008*¹⁵

MHRA *Guidelines for Magnetic Resonance Equipment in Clinical Use*²

11.3 Pulse sequence selection and parameter manipulation

Manufacturers often provide general guidance in their user manual with more specific advice available from applications support teams. If required, seek advice from your MR safety expert regarding pulse sequence selection and discuss with a radiologist or a suitably qualified radiographer the possibility of utilising a reduced protocol examination.

- ⚠ MR operators should utilise low SAR and quiet pulse sequences wherever possible

11.3.1 Reducing heating effects

Gradient echo sequences are generally less RF intensive resulting in less heating effects. Where possible, select low SAR pulse sequences.

- ⚠ It is essential to ensure patient weight is accurately obtained.

11.3.2 Reducing acoustic noise levels

Where possible, switch gradients into reduced acoustic noise mode, such as whisper or soft tone. Longer TRs, lower resolution, increased slice width and larger field of views will all reduce the dB/dt and, therefore, the acoustic noise generated. Echo Planar Imaging and other fast acquisition techniques will produce high acoustic noise levels and these should be carefully considered before their use.

11.4 Use of contrast agents in pregnant patients

Use of any Gadolinium Based Contrast Agents (GDCA) during pregnancy is not recommended unless absolutely necessary owing to the possibility of gadolinium accumulation in human tissues.³⁰

11.5 Pregnant staff

Under the Management of Health and Safety at Work Regulations,³¹ employers are obliged to undertake a risk assessment for expectant mothers relating to hazards caused by physical agents.

*In general, it is expected that the level of the time-varying electromagnetic fields, dB/dt, and the radio frequency will be relatively low except in the immediate vicinity of the scanning aperture. This may be of concern in the interventional situation. The level of the static magnetic field exposure is dependent on the field strength and shielding incorporated into the design of the magnet.*²

Further information available within the SCoR³² publication, available online:

<https://www.sor.org/learning/document-library/health-safety-and-pregnancy-clinical-imaging-and-radiotherapy-departments-guide-pregnant-women>

- ⚠ Risk assessments should be conducted for each MR scanner.
- ⚠ The MHRA recommends that throughout their pregnancy it is advisable that staff do not remain in the scan room while scanning is underway.²

12. Considerations for high field strength scanners (3T and above)

The use of higher field strength units in a clinical setting is increasing. The increased signal-

to-noise ratio (SNR) gained offers many advantages in clinical scanning. However, there are also further safety considerations and employers and staff need to be fully conversant with these. Staff will require further training in order to ensure patient safety. Employers should conduct a comprehensive risk assessment prior to the use of a new high field strength installation and there should be an independent set of local rules created.

12.1 Implantable medical and non medical objects

- ▲ **There must be no assumption made that because a device or implant is safe at 1.5T it will still be safe at field strengths of 3T and above. Departments should proceed with caution and if they are unable to obtain the required information then scanning should not take place.**

Departments should ensure that the implant or device has been tested up to the required field strength. For those listed as conditional at field strengths of 3T, departments should be fully aware of the conditions under which the device or implant can be safely scanned in liaison with the MR safety expert and manufacturer. A record of all implants and their MR safety status should be included within the local rules alongside processes for scanning patients with MR conditional implants.

12.2 Projectile and attractive forces

The attractive force on a ferromagnetic object is proportional to the spatial gradient of the magnetic field. This is normally steeper at higher fields particularly since active shielding is used to reduce the extent of the stray fields around the scanner. Therefore, objects including implants that have been found to be safe to use in the presence of 1.5 T systems may not be so with 3 T systems.¹⁵

- ▲ **Departments will need to reassess all equipment for use in 3T units that has been proved to be safe in 1.5T units. In particular, any equipment that is found to be conditionally safe at 3T must be carefully assessed, as the distance that an object can be safely kept from the magnet will alter at the higher field strength.**

Equipment should be clearly labelled as detailed in section 5.7

12.3 Specific Absorption Rate (SAR)

SAR is the measurement of energy deposited by an RF field in a given mass of tissue. SAR increases quadratically with field strengths. When using RF-intensive pulse sequences, such as Fast Spin Echo (FSE), Echo Planar Imaging (EPI) and Fluid-Attenuated Inversion Recovery (FLAIR) then SAR limits can quickly be reached, therefore, extra precautions should be taken to ensure patient safety. Manufacturers have developed many SAR reducing sequences and staff should be fully conversant with their use. See also section 7.1.1.

12.4 Peripheral Nerve Stimulation (PNS)

This effect is increased at 3T and the radiographer should be aware of methods to reduce this, by means of patient positioning, sequence selection and parameter manipulation if required.

12.5 Acoustic noise

The noise levels generated in a 3T system approaches twice those generated by a 1.5T system and can be in excess of 130 dBA. Higher gradient performance at 3T scanning also causes higher sound pressure levels.

12.6 Pregnancy

Please also refer to section 11.

12.6.1 Scanning of pregnant patients at 3T

Departments need to carefully assess the risks and benefits prior to making the decision to scan at the higher field strength: they should consider whether scanning at lower field strength such as 1.5T would adequately answer the clinical question. The decision to scan a pregnant patient at 3T should be clearly documented and the risks and benefits discussed with the patient.

12.6.2 Acoustic noise exposure and the foetus

Please refer to section 2.6.2 of the MHRA Guidance ²

12.6.3 Pregnant staff in high field strength units

Please refer to section 11.5

12.7 Design and planning of a high field strength unit

Where a department has several MR scanners of different field strengths, the design and layout of the unit should reflect the caution needed when imaging a patient who has an implant or device that is safe to scan only at the lower field strength in order to avoid the possibility of the patient entering the higher field strength unit. Accurate and clear labelling of distinct areas should be employed and local rules should reflect the need for a strict pattern of working that avoids patients being inadvertently scanned on the higher field strength scanner.

13. Contrast agents and other drugs

A variety of contrast agents and other drugs are used in the MR environment. Examples include gadolinium-based contrast agents (GBCA), liver-specific contrast agents, iron oxides, diazepam, antispasmodic agents such as buscopan and glucagon and diuretics such as furosemide.

13.1 Contrast agent injections should only be undertaken if clinically indicated and at the request of the supervising MR radiologist or radiographer who is appropriately trained and is authorised by the Clinical Director or Lead Radiologist. This authorisation should be documented in the local rules. Radiographers are permitted, under law, to supply and administer prescription only medicines (including contrast media) under patient group directions (PGDs) and, therefore, MR departments should have PGDs in place. If the drugs being administered are not prescription-only medicines, then PGDs are not required in law, although they are considered good practice. If an intravenous (IV) injection is to be given by a radiographer, that radiographer should be trained and competent in IV administration.³³ A register of contrast administration should be kept.

13.2 Patient consent should be sought in line with departmental protocols and all staff should be conversant with local emergency procedures.

13.3 Up to date information on supply, administration and prescribing of medicines can be accessed from the members section of the website: <https://www.sor.org/practice/other-groups/prescribing>

13.4 Gadolinium-containing agents are the most common contrast agents used in MR imaging. They are linked in varying degrees to a risk of nephrogenic systemic fibrosis (NSF). The European Medicines Agency and its Committee for Medicinal Products for Human Use (CHMP) reviewed the risk of nephrogenic systemic fibrosis (NSF) with gadolinium containing contrast agents³⁴ and classified them according to risk as follows:

High risk - Omniscan (gadodiamide), OptiMARK (gadoversetamide), Magnevist (gadopentetic acid)

Medium risk - MultiHance (gadobenic acid), Primovist (gadoxetic acid), Vasovist (gadofosveset)

Low risk - Gadovist (gadobutrol), ProHance (gadoteridol), Dotarem (gadotericacid)

13.5 Risk minimisation methods

The MHRA² has issued guidance regarding minimising the risk of NSF. This can be viewed on their website at the following link:

<http://www.mhra.gov.uk/Safetyinformation/DrugSafetyUpdate/CON087741>

⚠ **Departments should have, within the local rules, clear written procedures in place regarding the use of GDCAs in order to minimise the risk of NSF.**

13.6 Gadolinium retention in the brain

There is emerging evidence of gadolinium retention in the brain among patients who have undergone repeated contrast enhanced MRI scans.^{35, 36} The significance of this is yet to be determined.³⁷

The European Medicines Agency³⁸ is currently undertaking a review related to the risk of gadolinium retention in the brain.

Updates will be added to this publication as an addendum

14. Manual handling in MRI

Manual handling within an MR unit frequently involves the moving and positioning of cumbersome coils, heavy phantoms, other equipment and patients.

⚠ It is advisable for departments to ensure that there are storage units for coils at a corresponding height to the MR table top to avoid staff frequently lifting coils from floor to table top. If this is not feasible, for example on a mobile unit, appropriate measures should be put in place to minimise risks following a risk assessment. This may include, for example, altering the bookings to minimise coil changes throughout the day.

15. Fire and emergency safety and training

The static magnetic field means that extra considerations are required in the case of an emergency or fire within an MR unit. MR staff should be conversant with all safety procedures and practiced in the safe removal of patients in an emergency situation. We recommend that this is practised as a minimum 4 times per annum and on induction to the unit for new staff. Staff should be aware of the location of the fire extinguishers, quench buttons, oxygen monitors and departmental crash trolley.

▲ It is recommended that contact is made with the local fire unit to ensure that they are aware of the layout of the unit and safety considerations including the location of the quench button.

- 15.1** In the case of a patient emergency within the scan room such as cardiac arrest, the patient should be removed from the MR environment prior to the arrival of the resuscitation team and their equipment.
- 15.2** Clear fire procedures should be kept with the local rules. Staff should be aware of these and, in particular, under what scenario a quench would be required during a fire in the MR unit.
- 15.3** Staff should be aware of the circumstances under which they should quench a magnet and understand the implications of a magnet quench.

16. European Union Physical Agents Directive (EMF) EUPAD

16.1 Background

The European Union Physical Agents Directive¹ concerning **worker** exposure to Electro-Magnetic Fields (EMFs) was formally adopted in June 2013 with a transposition date of 1st July 2016. The Directive covers the minimum health and safety requirements regarding the exposure of workers to the risks arising from EMFs.

A copy of the published version can be viewed online:

<http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2013:179:0001:0021:EN:PDF>

- 16.1.1** In Great Britain, the Health and Safety Executive (HSE) is responsible for overseeing implementation. In Northern Ireland the responsible body is the Northern Ireland Health and Safety Executive (HSENI).

16.1.2 Derogations

The Directive includes a derogation for activities related to the installation, testing, use, development, maintenance of or research related to magnetic resonance imaging (MRI) equipment for patients in the health sector, from the exposure limit values, (ELVs) subject to certain conditions.

There are also conditional derogations for the military and a general temporary conditional derogation for specific activities subject to agreement with the overseeing authority for each member state. See 16.4.4

16.3 Requirements

HSE and HSENI have only introduced new requirements from the directive that go beyond current UK legislation.

HSE sets out its requirements in the Control of Electromagnetic Fields at Work

(CEMFAW) Regulations 2016.³⁹

Further information is available in a guidance document published by HSE
A guide to the Control of Electromagnetic Fields at Work Regulations 2016⁴⁰
<http://www.hse.gov.uk/pubns/books/hsg281.htm>

HSE NI

HSE NI sets out its requirements in The Control of Electromagnetic Fields at Work Regulations (Northern Ireland) 2016.⁴¹

<http://www.legislation.gov.uk/nisr/2016/266/contents/made>

Further information is detailed in an explanatory memorandum.⁴²

HSE NI states that the statutory rule will also be supported by the publication *A Guide to the Control of Electromagnetic Fields at Work Regulations 2016*⁴⁰

16.4 Exemptions

The CEMFAW Regulations (regulation 13(1))^{39, 41} grant HSE and HSENI power to exempt employers from the exposure limits contained in the regulations. Any exemption will be subject to safety conditions.

16.4.1 If an activity is exempt, employers must ensure that:

- exposure is as low as is reasonably practical
- employees are protected against health effects and safety risks arising from that exposure.

16.4.2 Employers will not be required to use measurements or calculations in their exposure assessment, or undertake an action plan, in relation to activities that are included in the exemption. **All other requirements of the regulations still apply to that work activity.**

16.4.3 Employers must still carry out risk assessments and ensure that workers are given appropriate information and training.

16.4.4 Exemption certificates

HSE and HSENI have published exemption certificates^{43, 44} containing information about activities which are exempt (under general temporary conditional derogation).

Available online:

<http://www.hse.gov.uk/radiation/nonionising/emf-exemption-certificate.pdf>

<https://www.hseni.gov.uk/publications/electromagnetic-fields-work-certificate-exemption>

16.4.5 Further information

Further information regarding exemptions is available on the following HSE and HSENI web pages:

<http://www.hse.gov.uk/radiation/nonionising/emf-exemptions.htm>

<https://www.hseni.gov.uk/articles/electromagnetic-fields-emfs#toc-5>

16.5 EU non-binding practical guidance

EU non-binding guidance^{45, 46, 47} has been published to assist implementation.

Available online: <http://ec.europa.eu/social/main.jsp?catId=82&langId=en&furtherPubs=yes>

17. Design and planning of units

- 17.1** It is essential that an MR radiographer is, from the outset, part of the project team for the design and planning of new or additional MR unit along with an MRI physicist, NHS estates or private company estates person, vendor's project manager and architect etc. It is also useful to include a member from the hospital's infection control team, nursing team, medical physics, manual handling and risk assessment departments to gain their input to the project as any equipment will need to be tested/certified and furniture/fittings should be ergonomically designed and comply with current standards.
- 17.2** It is important to obtain a copy of the pre-installation guidelines document from the magnet vendor as soon as possible, as that will give the specifics/particular requirements for the system.
- 17.3** There are numerous safety considerations related to site selection, site location, site access, quench pipe design considerations, location of scan rooms, control rooms, preparation rooms, storage of equipment, emergency equipment etc. For further information please refer to the MHRA guidelines.²

18. Further resources

The Society and College of Radiographers MRI web pages

<https://www.sor.org/practice/cross-sectional-imaging/mri>

The Society and College of Radiographers Magnetic Resonance Advisory Group

<https://www.sor.org/practice/cross-sectional-imaging/mr-advisory-group>

The British Association of MR Radiographers (BAMRR)

<http://www.bamrr.org/home>

The Institute of physics and Engineering in Medicine (IPEM)

<http://www.ipem.ac.uk/>

British Institute of Radiology

<http://www.bir.org.uk/>

Medicines and Healthcare products Regulatory Agency (MHRA)

<https://www.gov.uk/government/organisations/medicines-and-healthcare-products-regulatory-agency>

International Society for Magnetic Resonance in Medicine (ISMRM)

<http://www.ismrm.org/>

British Chapter

<http://www.ismrm.org/british/index.htm>

Section for Magnetic Resonance Technologists (SMRT)

www.ismrm.org/smrt/

Royal College of Radiologists

<https://www.rcr.ac.uk/>

Public Health England Non-Ionising Radiation Services

<https://www.phe-protectionservices.org.uk/nir>

Independent Advisory Group on Non-ionising Radiation (AGNIR)

<http://webarchive.nationalarchives.gov.uk/20140629102627/http://www.hpa.org.uk/Topics/Radiation/RadiationAdvisoryGroups/AdvisoryGroupOnNonIonisingRadiation/>

MRIsafety.com is the premier information resource for magnetic resonance safety. This web site is the official site of the institute for magnetic resonance safety, education, and research

<http://www.mrisafety.com/>

Health and Care Professions Council

<http://www.hcpc-uk.co.uk/>

EU Physical Agents Directive

SCoR webpage (log-in required)

<https://www.sor.org/practice/cross-sectional-imaging/european-union-physical-agents-directive-eu-pad>

Health and Safety Executive (HSE)

<http://www.hse.gov.uk/index.htm>

<http://www.hse.gov.uk/radiation/nonionising/directive.htm>

<http://www.hse.gov.uk/aboutus/europe/euronews/dossiers/emf-directive.htm>

Health and Safety Executive Northern Ireland

<https://www.hseni.gov.uk>

19. References

1. Directive 2013/35/EU of the European Parliament and of the Council of June 26 2013 on the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (electromagnetic fields) (20th individual Directive within the meaning of Article 16(1) of Directive 89/391/EEC)
2. MHRA Device Bulletin *Safety Guidelines for Magnetic Resonance Imaging Equipment in Clinical Use* March 2015
3. Society and College of Radiographers and the British Association of Magnetic Resonance Radiographers *Safety in Magnetic Resonance Imaging* London: SCoR, 2013
4. The Society and College of Radiographers *Scope of Practice of Assistant Practitioners* London: SCoR, 2012
5. IPEM Policy Statement: *Scientific Safety Advice to Magnetic Resonance Imaging Units that Undertake Human Imaging*. 2013
6. Health and Care Professions Council *Standards of conduct, performance and ethics*. London: HCPC, 2016.
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