Draft guidance for the planning of new MRI installations

February 2026

60 # Definitions

61

Term	Definition	Source of definition
B_0 Hazard Area	The space around the MR EQUIPMENT where the static magnetic field can cause HARM	IEC 60601-2-33
MR Conditional	An item with demonstrated safety in the MR Environment within defined conditions including conditions for the static magnetic field, the time-varying gradient magnetic fields, and the radiofrequency fields.	ASTM F2503-23
MR Controlled Access Area	A locally defined area of such a size to contain the MR Environment. Access shall be restricted and suitable warning signs should be displayed at all entrances.	MHRA 2021
MR Environment	The three-dimensional volume surrounding the MR magnet that contains both the Special Environment (Faraday shielded volume) and the B_0 Hazard Area (space around the MR equipment where the static magnetic field can cause harm). 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, and for which access control is part of the risk mitigation. **Adapted from IEC 60601-2-33**	ASTM F2503-23
MR Installer	The organisation that is responsible for the installation of the MR system. This may be the MR Manufacturer, but in some cases the installation may be subcontracted to separate teams or the MR system may be purchased from another supplier.	This guidance
MR Projectile Zone	A locally defined volume containing the full extent of the 3 mT magnetic field contour, or other appropriate measure, around the MR scanner.	MHRA 2021
MR Responsible Organisation	The organisation that is responsible for the use and maintenance of the MR system, e.g. hospital. Adapted here from the more general definition of a Responsible Organisation in IEC 60601-1, “The entity accountable	IEC 60601-1

	for the use and maintenance of a Medical Electrical Equipment or Medical Electrical System."	
MR Responsible Person	An individual within the MR Responsible Organisation to whom day to day responsibility for MR Safety is assigned. "It is recommended that the chief executive or the general manager delegate the day-to-day responsibility for MR Safety to a specified MR Responsible Person who might most effectively be the clinical director, head of the department, clinical scientist, medical physicist or MR superintendent radiographer of the institution where the equipment is located."	MHRA 2021
MR Safe	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, nonmetallic, and nonmagnetic.	ASTM F2503-23
MR Safety Expert	A general description of the role of the MR Safety Expert is provided in the JMRI consensus publication. The MHRA highlight the MR Safety Expert should be a designated professional with adequate training, knowledge and experience of MRI equipment, its uses and associated requirements.	JMRI consensus statement, doi: 10.1002/jmri.25282
MR Unlabelled	An item with no MR Safety labelling	MHRA 2021
MR Unsafe	An item which poses unacceptable risks to the patient, medical staff, or other persons within the MR Environment.	ASTM F2503-23
Special Environment	Electromagnetic environment with electromagnetic characteristics different from those specified in this collateral standard in Table 2 through Table 9 or that requires EMISSIONS limits, IMMUNITY TEST LEVELS or test methods that are different from those specified for the professional healthcare facility environment and the HOME HEALTHCARE ENVIRONMENT	IEC 60601-1-2

62
63

Figure 1 illustrates the different defined MRI safety zones around an MR scanner. The MR Projectile Zone, is the zone closest to the MR scanner that is associated with the attraction of ferromagnetic objects, potentially forming projectiles. Further out, is the B_0 Hazard Area, associated with unintentional reprogramming of active implantable medical devices. The Special Environment (Faraday shielded volume) is defined by the RF cage and is associated with risks from RF emissions from the MR scanner inadvertently impacting on other electrical equipment. The MR Environment encompasses any risks associated with the MR scanner and is a combination of the B_0 Hazard Area and the Special Environment (Faraday shielded volume). For examples, such as above, where the B_0 Hazard Area spills out into an adjacent room, the MR Environment is generally the combination of the MR Examination room and the controlled areas of the adjacent room. If the B_0 Hazard Area is contained within the MR Examination room, then the extent of the MR Environment can just be the extent of the MR Examination room. Finally, the MR Controlled Access Area, is the area the encompasses the MR Environment where access to the MR Environment is controlled.

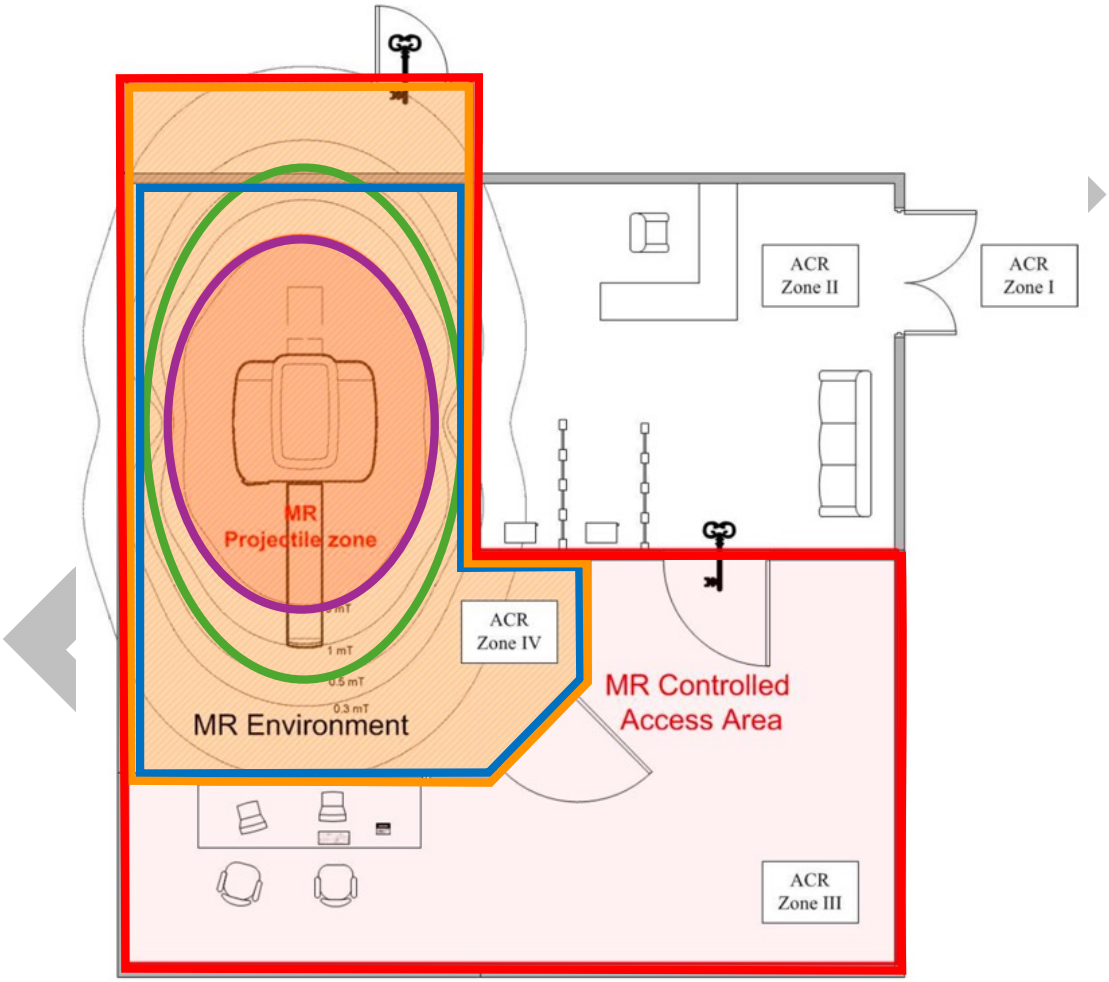


Figure 1. A example plan of an MR suite showing the different defined MRI safety zones around the MR scanner; the MR Projectile Zone, (purple), the B_0 Hazard Area (green), the Special Environment (blue), the MR Environment (orange) and the MR Controlled Access Area (red).

Abbreviations

HBN	Health Building Note
HSE	Health & Safety Executive
HTM	Health Technical Memorandum
NHSE	National Health Service England
RIBA	Royal Institute of British Architects

List of tables

List of figures

1 Introduction

This guidance provides support for the planning, installation, acceptance and subsequent use of new clinical MRI installations. It has been drafted with a UK focus, but it is anticipated that many aspects of this guidance may be relevant more generally to new clinical MRI installations. This work links in with the MHRA guidelines for MR Safety (MHRA 2021), the primary authority for MR Safety guidance in the UK, as well as more general MHRA guidance on the management of medical devices (MHRA 2021a). These guidelines have been developed in parallel with the forthcoming update of the NHS Health Building Note 06-01 (HBN 06-01) that provides more general guidance for diagnostic and interventional imaging. Where relevant, reference is made to other HBNs[1] and Health Technical Memoranda (HTMs)[2]. Note, Wales and Scotland publish versions of the HBNs and HTMs applicable to their national health systems. Finally, this guidance incorporates some site planning information provided by individual MR manufacturers.

The target audience for this guidance are MR staff, hospital estates and facilities professionals, architects, engineers and other professional groups involved with the planning of new MRI installations. This document is written predominantly with the fixed installation of superconducting horizontal bore whole-body MR systems in mind (generally 1.5T or 3T), since these are currently the most common. However, this guidance is expected to be helpful to those planning to install other designs of MR scanner, including mobile scanners, MR systems based on permanent or resistive magnet system designs, and superconducting systems that do not require a helium quench pipe. This guidance aims to makes suggestions based on considered best practice, while recognising that in many cases there may be a local need for variations. NHSE also publish a guidance on managing and reporting derogations from HBNs, HTMs and other NHS estates related standards or guidance documents (NHSE 2023).

This guidance has been drafted by a multi-professional working group with representation from the following stakeholders.

- Architects for Health
  - Hal Jones, Floyd Slaski Architects
  - Franko Covington, Building Design Partnership Ltd
- Association of Anaesthetists
  - Chloe Fairbairns, South Tees Hospitals NHS Foundation Trust
- Association of Healthcare Technology Providers for Imaging, Radiotherapy and Care (AXREM)
  - Craig Buckley, Siemens Healthineers
  - Terry Heathcote, Siemens Healthineers
  - David Martin, formerly Siemens Healthineers
  - Matthew Clemence, Philips Healthcare
  - Clare Harris, Philips Healthcare
  - Gavin Houston, GE HealthCare
  - Allen Munt, GE HealthCare
  - Chris Wilson, GE HealthCare
  - Huw Shurmer, Fujifilm
  - Megan Newberry, Fujifilm
  - James Davies, Easote
  - John Manchester, Easote
  - Gary Fletcher, McNaughts
- British Association of Magnetic Resonance Radiographers

[1] A complete list of HBNs is available at https://www.england.nhs.uk/estates/health-building-notes/

[2] A complete list of HTMs is available at https://www.england.nhs.uk/estates/health-technical-memoranda/

    - Rachel Watt, NHS Grampian
- British Institute of Radiology
    - Martin Graves, University of Cambridge
- Institute of Healthcare Engineering and Estate Management
    - Andrew Ward, NHS Wales Shared Services Partnership
- Institute of Physics and Engineering in Medicine
    - David Price, Guy's & St Thomas' NHS Foundation Trust
    - Maria Schmidt, Royal Marsden NHS Foundation Trust
    - Cormac McGrath, Belfast Health & Social Care Trust
    - Dan Wilson, Leeds Teaching Hospitals
    - Siân Curtis, University Hospitals Bristol and Weston NHS Foundation Trust
    - Geoff Charles-Edwards, Guy's & St Thomas' NHS Foundation Trust, Royal Marsden NHS Foundation Trust
    - Rebecca Quest, Imperial College Healthcare NHS Trust
    - Mike Hutton, The Christie NHS Foundation Trust
- Medicines and Healthcare products Regulatory Agency (MHRA)
    - David Grainger, MHRA
- Royal College of Radiologists
    - Mark Radon, Walton Centre NHS Foundation Trust
- Society and College of Radiographers (SCoR)
    - Alex Lipton, Society and College of Radiographers

Contributions from the following individuals during the preparation of this guidance are gratefully acknowledged.

- Niven Smith & Shane Greenwood, Envirotect Ltd
- Ilhem Toumi & Jean-Pierre Fronte, ETS-Lindgren
- Tobias Gilk, Gilk Radiology Consultants
- Gordon McKenzie, Imedco
- Michael Steckner, MKS Consulting
- Alexandra Guthrie & Sandy Thompson, National Fire Chiefs Council
- Abigail Pride & Michael Rope, NHS England
- Michael Bernard, Andy White & David Haire, Siemens Healthineers
- Yvonne Kinsella, UK Health Security Agency

In preparing this guidance, the working group invited the wider MRI community to share real-world examples of issues encountered with new MRI installations, particularly those that might have been avoided or reduced with greater awareness and consideration of relevant issues and more informed decision-making. Selected submissions are presented throughout this guidance as short case examples that aim to highlight the relevance of specific recommendations. In several cases, multiple contributors reported the same or similar issues. All contributions are gratefully acknowledged.

This guidance is structured into various phases, mapping onto the Royal Institute of British Architects (RIBA) work stages (RIBA 2020) that are widely used in many NHS capital development projects.

- **Project brief & feasibility (RIBA stages 0-1)**. This covers initial work to consider what is required, the feasibility of different options, typically leading to the development of a strategic outline case (SOC).
- **Design (RIBA stages 2-4)**. This covers the full design of the MRI installation.
- **Build (RIBA stage 5)**. This section covers the building works for a new MRI installation.
- **Installation (RIBA stage 5)**. This section is concerned with the installation of the MRI equipment itself.

- **Acceptance (RIBA stage 6)**. This phase covers the checks performed on behalf of the purchaser that ultimately lead to formal acceptance and handover of the MRI installation.
- **Use (RIBA stage 7)**. This phase highlights issues relating to the use of the MRI installation.

The governance of NHS capital development projects often starts with the production of a strategic outline case (SOC), which if approved progresses to an outline business case (OBC) and ultimately a full business case (FBC), capturing the project's design with regards to financial, management and operational aspects. Figure 2 shows how these governance stages often map to the phases in this guidance and in turn onto to the RIBA work stages. Importantly, this alignment to the RIBA work stages is indicative and this may vary for individual projects. For example, a SOC might include RIBA Stage 2 Concept Design due to project-specific characteristics. Typically, construction will not start until approval of the Full Business Case (FBC) which normally precedes the release of funding for work to commence. Additionally, the order for the MR system is typically placed after the FBC is approved. Project teams therefore need to plan for a period of design coordination at the start of RIBA Stage 5, when the MRI suppliers are fully engaged and ready to prepare their final drawings. However, earlier coordination can help to lower the risks. A period of final coordination with the MR supplier may also be covered prior to Stage 5 via a Pre Contract Services Agreement (PCSA). Completing the design and coordination with the MR supplier will enable the Principal Contractor to finalise the proposed contract sum and construction programme.

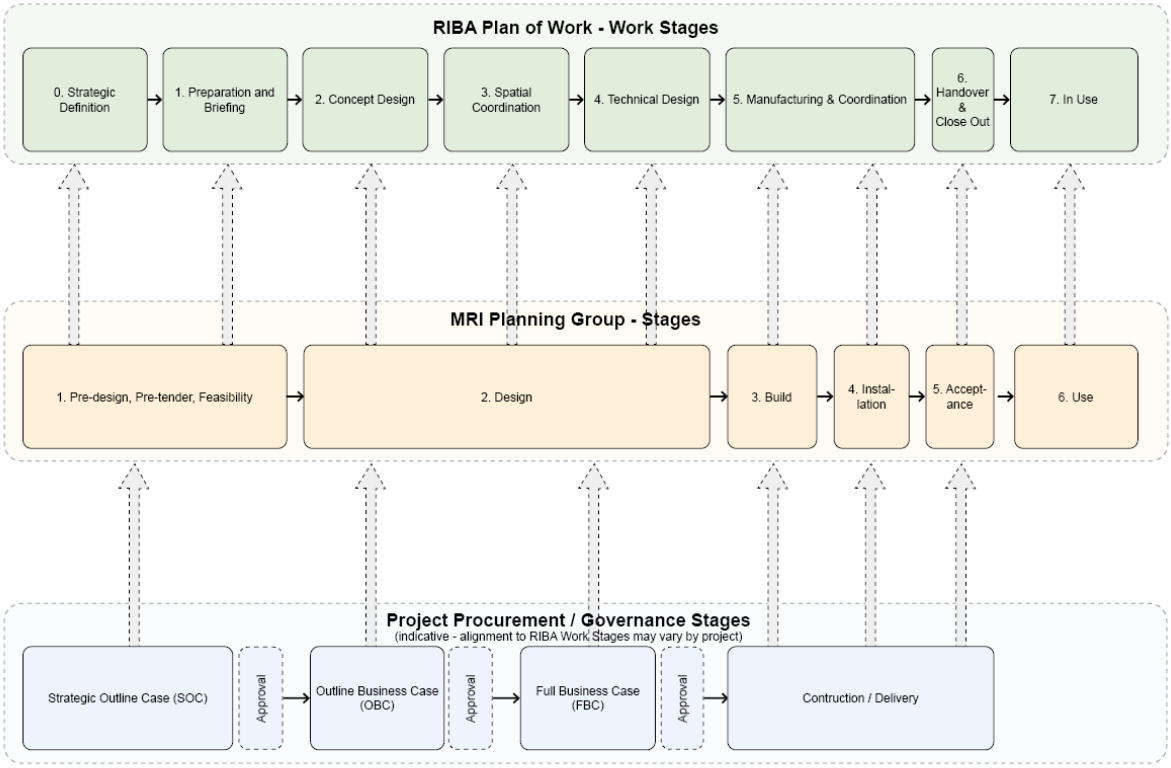


Figure 2. Mapping of typical governance stages and MRI installation project phases to the RIBA plan of work stages.

For building projects that fall within the Building Safety Act definition of Higher Risk Building (HRB), the RIBA Stage 4 design proposals must be fully coordinated with the MR supplier's proposals prior to making the building regulations application (Gateway 2). RIBA Stage 5 Construction work must not start until approval from the Building Safety Regulator is granted. An RIBA Stage 4 PCSA period or equivalent would be appropriate for an HRB process. During the PCSA all specialist design

subconsultants, that are relevant to building regulations compliance, such as mechanical and electrical subcontractors, RF cage designers, fire stopping specialists, etc need to be appointed to ensure a fully coordinated and demonstrably compliant design.

This guidance does not aim to provide detailed recommendations on procurement, although a few general points are included here as initial suggestions. Although there are national procurement schemes, different organisations may have individual approaches to tendering and procurement of new equipment. Consequently, it is important to engage with procurement colleagues within the local organisation early on in a new MRI installation project to seek guidance on the local processes and options available. The following national bodies that provide further advice.

- England: NHS Supply Chain: for contractual and purchasing procedures. MR scanners and associated option and related services, https://www.supplychain.nhs.uk/product-information/contract-launch-brief/magnetic-resonance-imaging-scanners-and-associated-option-and-related-services/
- Scotland: contact Scottish Healthcare Supplies
- Wales: contact Welsh Health Supplies for procurement matters and Welsh Health Estates for Technical and Estates related issues. https://nwssp.nhs.wales/ourservices/specialist-estates-services/our-services/diagnostics-and-therapies/
- Northern Ireland: contact the Department of Health, Social Services and Public Safety (DHSSPS)

Additionally, the MHRA's guidelines for the management of medical devices (MHRA 2021a) provide some recommendations on appropriate acquisition and selection. Importantly, while resources such as the NHS supply chain can provide a helpful overview of available MR systems (NHS Supply Chain 2025) this information may not be complete/up-to-date and confirmation from the MRI manufacturers is recommended. Many new MRI products are announced at the Radiological Society of North America (RSNA) annual meeting that historically has occurred at the end of November each year, although some options may not be immediately available to purchase. Additionally, new MRI products have been announced at other scientific meetings such as the European Congress of Radiology (ECR) and the International Society of Magnetic Resonance in Medicine (ISMRM).

The range of options for an individual MR system can be very broad, particularly for software-based options, and additional complexity may arise where MRI manufacturers group certain options together. To help provide clarity on what is included in any tender offer it is recommended to request a corresponding list of items that are **not** included in any offer.

Real-world example: misunderstanding over what was included in tender

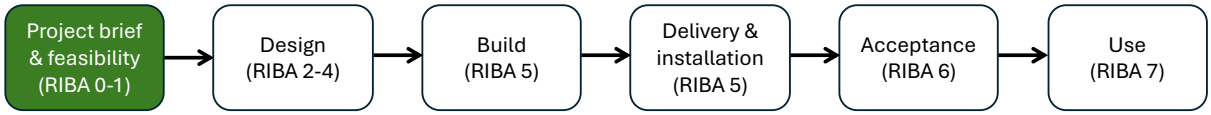
It was misunderstood by MR staff that the list of options purchased with an MR system included one for extended table movement that was required to support a need for whole-body MRI scanning. This was not identified until after the MR system was installed.

Impact: The MR system was unable to provide whole-body MRI examinations until the MR system was replaced 15 years later.

Where possible, it is strongly recommended to visit sites who already have been working with the MR system under consideration, to discuss their experiences. Typically, MRI manufacturers are able to help with organising such visits.

Often, a small proportion of the total cost of the MR system is held back until the system is accepted. Consequently, it is important to identify what the acceptance criteria should be and to specify these as part of any invitation to tender.

2 Project brief & feasibility (RIBA stages 0-1)



2.1 Introduction

This section highlights aspects of MRI site planning that are recommended as part of developing the project brief and assessing the feasibility of location options for a new installation. These steps are performed prior to the formal design phase.

At the end of this phase of the project there should be enough information to allow a high-level comparison of advantages and disadvantages of different options, including basic costings, that can be used to produce a strategic outline case (SOC).

2.2 Client team

The client team are responsible for compiling the project brief that is required to inform the design (RIBA 2020). They are also key to each subsequent stage in the project, providing clarifications and oversight to help ensure the project meets their vision as much as possible. Some members of the client team may additionally contribute to, or be part of, the design team. Table 1 highlights several individuals and groups that are important to consider involving within the client team for new MRI installations. HBN 00-01, that provides general design guidance for healthcare buildings, highlights the importance of patient and public involvement in strategic planning. This is echoed by patient bodies such as the Patients Association, who encourage involvement of patients and carers in the design of local diagnostic services (Patients Association, 2024).

Key individuals/groups	Key roles and responsibilities in this project phase
MR service manager	To help define the clinical need and workload and to ensure that the facility can support all required processes. Share existing MR department management policy documents with the project team.
MR Clinician	To support definition of the clinical needs for the project. It is expected the clinical specialty will match the MRI service, i.e. a radiologist for a radiology-led MRI service, a cardiologist for a cardiology service
Supporting clinical services where relevant (e.g. anaesthetics)	To help provide high level requirements with regards supporting clinical services
MR Responsible Person	To ensure appropriate MR Safety within the project brief
MR Safety Expert	To provide technical expertise to ensure appropriate MR Safety within the project brief.
MR physicist	To provide technical expertise to support more general physics aspects for defining the project brief.
IT personnel	To ensure any new facility meets the need of the users in communication, data management and security, access to PACS and other relevant systems. Their involvement may be more substantial in the design phase, but it may be helpful for them to be involved earlier to help identify potential issues.

MR manufacturers	Although the formal tender process may not start until the end of the design phase once the full business case (FBC) has been approved, MRI manufacturers will often be able to provide valuable support at this phase of a project and their engagement is recommended as early as possible. A pre contract services agreement (PCSA) may be considered if required.
Hospital Estates	High level overview on location options and risks, e.g. power supply, structural information, long-term site plan, etc. Additionally, provision of 'golden thread' building information to the project team to satisfy Building Safety Act, e.g. power supply, water supply, structural information, fire safety information etc.
Design Team – including statutory Principal Designer duty holder roles.	High level overview on design options and risks, e.g. overall area available for MR Controlled Access Area, structural slab to slab height and loadings, MRI access for install and replacement, quench pipe route, MEP infrastructure and plant space, adjacent areas that may affect or be affected by the magnet, broader building context issues – patient flows, fire safety, construction access etc. Identify all designer appointments, their scopes of work and establish the designer's responsibility matrix.
Healthcare planner	Sites may consider utilising the services of a Healthcare Planner to help lead the development of stakeholder consensus and overseeing its synthesis throughout the design and planning process. Support from a healthcare planner may be more relevant for larger developments where capacity planning and clinical flow assessment is required.

Table 1. Key individuals and groups specific to new MRI installations that should be considered for the client team.

2.3 General clinical requirements

Cleary defining the general aims and requirements of a new MRI installation is a crucial first step to enable identification and comparison of feasible options. A key component of this is to define the different patient cohorts and MRI services that are to be accommodated. The requirements for an MRI installation aiming to provide basic MR imaging services for ambulatory out-patients may be quite different from one designed for in-patients. A key decision here is whether to include provision for anaesthetic cases at some point during the expected lifetime of the MR system, since modifications to an operational MR suite to introduce the capability for anaesthetic cases may be more limited, costly and disruptive. Another key decision is the potential need to support paediatric patients as well as specialised procedures such as MRI for radiotherapy planning, intraoperative and interventional MRI services. An MR system aimed at performing only head MRI scans may not require the full scope of patient table movement through the scanner, which subsequently may allow for compromises in the size of the MR Examination room.

Defining the expected patient cohorts also helps with the additional step of identifying any additional stakeholders to provide high-level advice regarding clinical requirements for this stage of the project. Nursing or anaesthetic teams may accompany in-patients; other patients may be accompanied by carers or hospital staff, translators and religious/cultural chaperones, all of which

may require additional space. Paediatric patients, general anaesthetic procedures, mental health patients, prisoners, and advanced procedures which include extra ancillary equipment such as radiation therapy treatment planning or MR guided focussed ultrasound will all have different requirements. HBN 06-01 provides general guidance regarding the pathway for different patient groups, as well as functional relationships, workflows and logistics for the planning of new MR suite.

The general clinical requirements should consider the overall workload, since this can impact on general space requirements in addition to more specific aspects in the design phase. Additionally, consideration should be given to the potential for future expansion of services to be undertaken. Finally, operational continuity and the level of resilience should be defined, since this will impact the design, particularly regarding engineering specifications.

2.4 General space requirements

MRI installation projects generally fall into one of the following types

- Replacement of an existing MR scanner with no, or minimal, changes to the building,
- Installation of a new MR scanner into a re-purposed existing building. This may include expansion of an existing MR suite.
- Installation of a new MR scanner in a new purpose-designed building.

The space requirements for each of these may vary significantly. Additionally, an independent department is likely to require a larger footprint than an MR suite within a larger imaging department where facilities such as reception and waiting areas can be shared.

Although MR manufacturers provide specifications regarding minimum space requirements for a particular MR system, this may be focussed on the minimum to accommodate the equipment without consideration of how the system is to be used. Designing solely to manufacturer minimum specifications, without reference to clinical workflows and patient cohorts, is likely to result in operational constraints, reduced throughput, compromised patient experience, and the need for costly retrospective modifications once the MRI service becomes operational. It is important that the overall space requirements for an MRI installation are defined by the overall clinical need. Ignoring this and simply designing to an MR manufacturer's minimum specifications can have serious negative implications for when the MR suite becomes operational, again highlighting the importance of defining the expected patient cohorts and workflows as the first step in any new MRI installation.

HBN 06-01 provides general guidance on space requirements for MR installations, including the following.

- Patient access: Patients may not be ambulant, may require transfer to an MR Conditional wheelchair or bed. In-patients may need to be transported in a bed, and thus require wider corridors, turning points and a location for the transfer to an MR-Safe/Conditional trolley.
- Patient Facilities: Space for private conversations when screening patients is essential; activities requiring private space also include giving consent to procedures (clinical and research) and counselling. Furthermore, patients require changing facilities, lockers to store their belongings, access to a toilet and drinking water. Separate areas for paediatric patients are desirable, and all patients require privacy. Some patients will be accompanied by chaperones, guardians, carers, and translators. Poorly designed or under-dimensioned waiting areas may limit the patient throughput.
- Examinations under General Anaesthetic or sedation: space required for equipment, personnel, and activities such as patient preparation and recovery. A separate space for paediatric procedures is desirable. GA personnel take up space either in the control room or MR Examination room during examinations.

- Clinical Procedures: Space is required for cannulation of patients prior to the examination and recovery from invasive procedures (MR-guided biopsies and others). Staff require handwashing facilities in the vicinity of those activities. First aid, addressing allergic reactions and adverse events, resuscitation and other clinical interventions require a dedicated private space and equipment that must be stored in the vicinity. Some clinical procedures require bowel and bladder preparation, and are only viable if a toilet is available very close to the MR scanner.
- Storage: Auxiliary equipment such as an MR Conditional bed and wheelchair, trolleys and stepladders must be available to the MR Unit. Other specialist activities require equipment to be stored: MR-guided focussed ultrasound, Radiotherapy planning accessories, MR-guided biopsies, etc. GA equipment needs storing when not in use, and some equipment needs charging (e.g. injectors). Although equipment does not need to be stored within the MR Controlled Access Area, there are many advantages in having dedicated equipment in MRI, as the workload in checking whether they are MR Safe /MR Conditional is significant.
- Administration: Administrative tasks require a separate space and a degree of privacy. Administrative personnel make direct contact to the general public and may need to enter/leave the MR Controlled Access Area frequently.
- Staff Facilities: MR Staff require changing facilities and storage space for their belongings. MR staff need access to rest areas for breaks.

These are discussed further in the design section of this guidance.

A more specific space-related decision for the local site to consider at the start of the project is what static magnetic field threshold will be used in the project for controlling access to the high magnetic fields around the MR scanner to protecting against inadvertently changing the function of pacemakers and some other implantable medical devices, an area now defined as the B_0 Hazard Area. Historically, this threshold has been 0.5 mT, with the primary reference for this being the international standard IEC 60601-2-33. However, a recent update to this standard (published in the UK as BS EN IEC 60601-2-33 (2024)) increases this threshold to 0.9 mT. The main benefits of this change are increased flexibility for the installation of MR systems into limited spaces with potentially significant cost savings as demonstrated by Figure 3 (reproduced from Steckner *et al*. 2024). However, although the new 0.9 mT limit has been recognised in the recently updated ACR manual on MR Safety, at the time of writing (Feb 2026) the MHRA guidelines have not yet been updated to reflect changes in BS EN IEC 60601-2-33 (2024). Where a threshold above 0.5 mT is adopted, the MR Responsible Organisation should explicitly document this decision, including the clinical and safety rationale, stakeholder agreement, and any additional risk mitigations. Particular consideration should be given to the presence of patients, staff, or visitors with implantable medical devices, and to alignment with current national guidance. This decision should be reviewed if national guidance is updated.

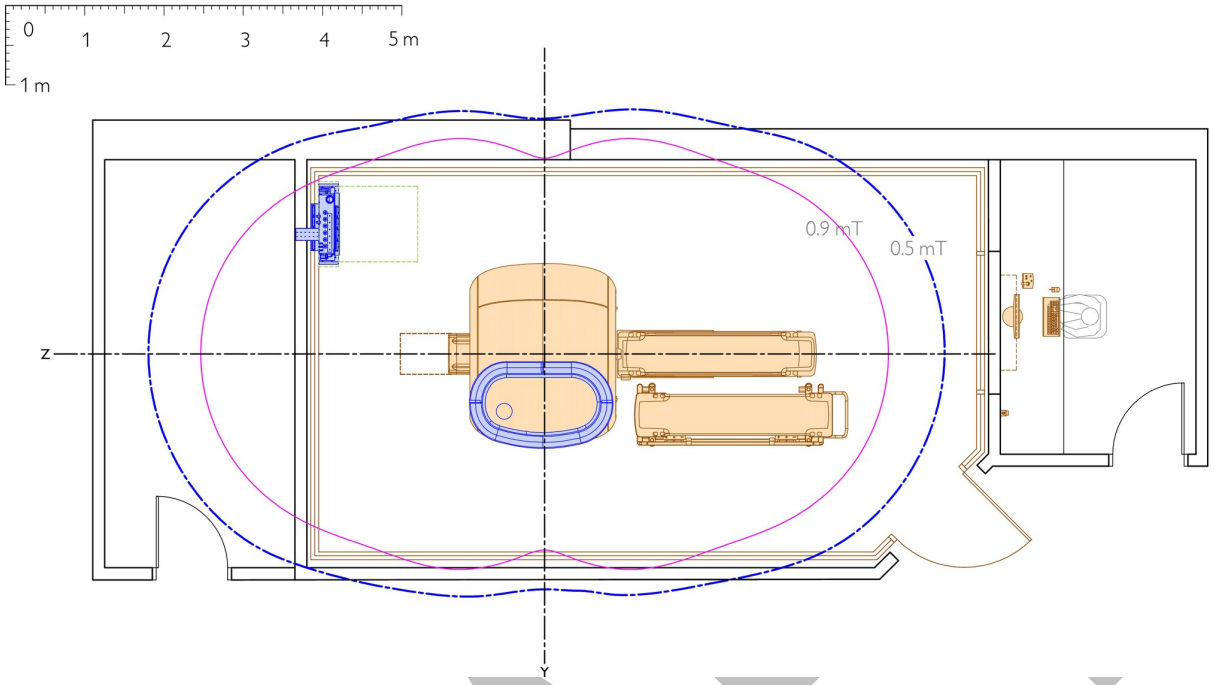


Figure 3. Magnetic field isocontours overlaid on plans of a 1.5 T MR suite. In this example, if the B_0 Hazard Area is defined by the 0.5 mT threshold then magnetic shielding in both side walls/access control is required for the areas where the 0.5 mT fringe field (blue) protrudes slightly from the MR Examination room. This is not required if the B_0 Hazard Area is defined by the 0.9 mT threshold (pink). Both fringe fields extend into the MR Technical room at the back of the MR scanner which therefore requires access control in either case.

2.5 General MR system requirements

Once the general clinical aims for a new MRI installation have been established, it is necessary to consider some general requirements for MR systems to help rule out unsuitable location options early in the project. MR manufacturers provide lists of requirements as part of their site planning guide (sometimes known as a preinstallation manual) for specific MR scanner models. These site planning guides are generally accessible and the client team are encouraged to seek copies from MR manufacturers that are likely to be of interest. Additionally, involvement of representation from the MR manufacturers at this stage in the project can be helpful to provide general guidance when exploring location options for a new MR installation.

It is in the interest of the users for a site to be as compliant as possible with the site planning guide for the selected MR system to enable the manufacturer to meet their own performance specifications for the MR scanner. Since selection of the MR system will typically occur later in the project, it may be helpful to consult site planning guides for a number of potential MR systems and to apply additional margins to stated specifications to cover the uncertainty of the selected MR system as well as provide flexibility for a future upgrade/replacement.

Proximity of MR scanner to neighbouring equipment and moving metal objects

The MR scanner can be adversely affected by nearby equipment and large moving objects, resulting in impaired image quality. One example is the presence of a neighbouring MR scanner. Site planning guides list minimum distances between the isocentres of two scanners to avoid each impacting on

the other in terms of the magnetic field homogeneity. Typically, these distances depend on the orientation of the magnetic field in relation to each other. Installing scanners closer than the recommended minimum separation distance may add cost and downtime during installation (and at other stages such as during remedial work and replacement) as they may require simultaneous magnetic field shimming.

The MR manufacturers site planning guides typically included recommendations regarding minimum distances between the location of an MR scanner and large moving objects such as lifts, differently sized motor vehicles, trains and linear accelerator gantries, based upon their estimated mass. Additionally, electrical current in high voltage power lines, transformers, switches, motors, or generators near the magnet may also affect the MRI magnetic field homogeneity. Site planning guides provide further details, often specifying a threshold for permitted current or distance of the equipment from isocentre. These thresholds may vary with the electrical current AC frequency.

The introduction of passive magnetic shielding (typically high permeability steel) can help to reduce these requirements slightly, although these are considered less effective for low frequency variations. However, active compensation systems are available which report an ability to reduce low frequency environmental magnetic field variations by two orders of magnitude. It is important to recognise the limits to which passive and active magnetic shielding can help support a non-ideal location for an MR system.

Since the usage of plant rooms change over time, often with the installation of new equipment at higher power rates, additional margins should be considered to avoid potential issues in the future. In case of doubt on the suitability of a particular site for an MRI installation, it is possible to perform a B_0 test and measure the temporal magnetic field fluctuations at a particular proposed isocentre position, across a range of frequencies. This requires specialist equipment and is time consuming and expensive. Therefore, it is only viable to proceed with B_0 tests for a few selected sites which have been pre-screened and appear to be suitable. The B_0 test in itself relates to field fluctuations during the period of time that the measurement takes place. Consequently, it is important to ensure that the measurement made during a period of representative use of the building. If required, there are options for magnetic shielding to limit the effects of these external magnetic field fluctuations on the MR scanner.

Additionally, the fringe static magnetic field from the MR scanner may adversely impact other equipment in the immediate vicinity to the MR Controlled Access Area. In a hospital setting, equipment that may be particularly sensitive to the fringe magnetic fields include gamma cameras, PET scanners, CT scanners, X-ray analogue image intensifiers and linear accelerators. Maximum permissible magnetic flux density (mT) levels for various pieces of equipment are often included in the MRI manufacturers site planning guides, although it is recommended to consult the manufacturers of the neighbouring equipment for requirements more specific to the item of equipment.

It is possible to use passive magnetic shielding to limit the extent of the magnet fringe fields outside of the MR Examination room. In addition to cost implications, passive magnetic shielding is also heavy, and may take up some MR Examination room space; it must be planned at early stages, as part of the building structure. The amount of shielding required is calculated by vector field simulation of the magnetic field. This is performed by MRI manufacturers or specialist companies. Additionally, MR manufacturers typically specify minimum distances between any shielding and the MR scanner.

MRI manufacturers will have a minimum ceiling height for magnet installation to allow access to the top of the magnet. There must also be sufficient space above the false ceiling for the necessary services to be run, particularly ventilation ducting.

Structural requirements & delivery/removal routes

The weight of whole-body MR scanners varies considerably. This has immediate implications for the structural requirements of potential locations, both in terms of the final position of the MR scanner and for delivery/removal routes. Such structural requirements should feed into the planning of new buildings and need to be checked for existing buildings. If magnetic shielding is to be used to limit the extent of the MR Environment into areas adjacent to the MR Examination room, the weight of this shielding must also be taken into consideration. Structural changes to existing buildings can be considered to support additional loads if required.

Additionally, MR systems typically have requirements in terms of mechanical vibration. Special vibration absorbing mounts may be required in some cases where levels of vibration may be of concern. It may be advisable to carry out a vibration survey of any proposed sites for a new MRI installation to establish typical levels, and vibration requirements should be considered as part of the design of a new building.

In addition to supporting the magnet weight, there are restrictions on the ferromagnetic content of slabs and walls close to isocentre described in all site planning guides. A high ferromagnetic content may compromise the field homogeneity, making it impossible to shim the magnetic field to meet the manufacturer's specifications. The ferromagnetic content is not necessarily known in existing buildings, particularly if the buildings are very old. As a result, it may be necessary to drill the slab for samples to be tested. Upgrading and modifying parts of the structure of older existing buildings can be prohibitively expensive, and therefore structural matters must be considered early in the site planning process.

It is important to consider the delivery route for each potential location of a new MR system at the early stages of the project, as it can have a significant impact on installation costs and in some case may rule out potential locations options. Delivery routes may involve lifting the magnet over existing buildings. There may be a need to reinforcing the floor (temporarily or permanently) along the delivery route to allow the translation of the magnet to its location; deliveries to upper floors and listed buildings require particular attention. The MR manufacturers site planning guide will confirm the minimum clear dimensions required for access. Consequently, it is often preferable for MR Examination rooms to be located with or close to an external wall to aid delivery and future removal of the MR scanner, which also reduces the risk of changes over time that prohibit the same delivery route being used for the future extraction/replacement of the MR scanner. If the new MRI installation project includes construction of the building, then the building fabric should be designed so that the relevant section of external wall or roof can be removed and reinstated for future MRI replacement.

Consideration of the local site development control plan is important to identify if any proposed locations for new MRI installations are at future risk with regards other proposed projects that may impact on the access route for a future replacement of the MR system. It is also important to maintain an access route throughout the lifetime of the MR system for the replacement of large components of the MR system, e.g. the gradient coil, in the event of failure, and for deliveries of liquid helium that additionally requires consideration of associated legislation such as the Pressure Systems Safety Regulation.

Real-world example: Delivery/removal route for MR scanner not maintained

During the lifetime of an MR system, a new building was constructed, blocking the original and only route for MR scanner delivery/removal.

Impact: At additional cost to the institution, the MR scanner was cut up into pieces to allow removal and reutilisation of the space. Associated loss of potential income from resale of magnet.

598

Real-world example: Delivery/removal route for MR scanner not maintained

During the lifetime of an MR system, the original and only route for MR scanner delivery/removal was removed.

Impact: The MR scanner was bricked up and left in situ, with subsequent loss of functional space within the hospital building.

599

Real-world example: Delivery/removal route for MR scanner not maintained

During the lifetime of an MR system, the original and only route for MR scanner delivery/removal was enclosed behind a new facade to the hospital.

Impact: Sections of the facade to the hospital had to be removed at an additional cost of around £70K to enable access/removal/replacement of the MR scanner.

600

601 ## Chillers

602 An MR scanner generally requires a continuous and uninterrupted supply of liquid coolant. This is
603 typically provided by a dedicated chiller. Different parts of the MR system require cooling,
604 depending on the specific design. In general, the most critical item is the compressor head
605 (coldhead) which minimises the helium boil off rate. Interruption of the supply of cold water has
606 serious implications, as it will cause cryogens to evaporate more quickly, and their replacement is
607 costly. Therefore, the design of the chiller plant is also critical.
608
609 While basic specifications for the chiller are provided by MR manufacturers in their site planning
610 guides, consideration should be made early in the project to the provision of a backup chiller
611 solution based upon how critical the continued operation of the MR scanner is to the institution.
612 Importantly, problems with chillers resulting in downtime of clinical MRI services are one of the
613 most frequently quoted frustrations by MRI users. The design and provision of resilient critical
614 services is a key element to all building engineering services within healthcare as outlined in HTM 00
615 core standards (Appendix A). Duplicate or shared load designs increase reliability and reduce the
616 probability of clinical disruption. Additionally, they may help with preventative maintenance to the
617 plant equipment with minimal disruption to the clinical service. For some MR systems, a backup
618 chiller is listed as essential in the site planning guide. Notably, at least one of the main MRI
619 manufacturers reports that the majority of new MRI installations now incorporate a backup chiller to
620 minimise the likelihood of MR system downtime.
621

Real-world example: No backup chiller solution

A clinical MR scanner with no backup chilled water solution was down for around 2 weeks when one of the components in the chiller failed and there was a long lead time on sourcing a replacement part, despite the chiller being maintained and serviced by an established contractor. The hospital was also liable for costs of replacing the helium that was lost during this period.

Impact: MR scanner down for 2 weeks

Temperature and humidity

MRI requires control of environmental temperature and humidity for the MR Examination room and equipment room (and sometimes the MR control room), with specifications provided by MR manufacturers in their site planning guides. Therefore, decisions must be made early in the planning process on whether MR will have a dedicated air handling unit (AHU) or whether this provision will be integrated with other facilities within the institution. As part of this, particular consideration should be given to humidification/dehumidification the reliability of solutions for humidity control. Low levels of humidity increase the risk of image quality problems and MR manufacturers may refuse to troubleshoot MR systems if the room humidity is consistently too low. Too high humidity levels impact on patients' ability to thermoregulate during the MRI scan and are therefore a safety issue. HTM 03-01 provides general guidance on ventilation.

Power Supply

The power requirements for an MR scanner and supporting plant can be significant compared to other radiological equipment. Consequently, it is important to establish early on the maximum power requirements for potential MR systems and supporting plant, and to confirm whether these can be met at each of the locations being considered for siting the MR system. Where the available power is insufficient to meet the highest requirements, this will need to feed into identification of MR systems that can be supported. Again, consideration should be made for potential future upgrades with increased power requirements, such as higher imaging gradient performance.

General advice on the power supply requirements for MR systems is provided in HTM06-01, although more up to date information may be provided by the MR manufacturers.

Repurposing an existing RF cage

Keeping an existing RF cage may be considered for projects where an MR scanner is to be replaced/upgraded without any structural changes to the MR Examination room layout. In these cases, a measurement of attenuation levels of the RF cage early in the project is important to establish its current performance and whether this is meeting MR manufacturer specifications, although it is recognised that many MR scanners may be operating without problems within RF cages that have a performance that is below the MR manufacturer's original specification (Small *et al*. 2026). Where specs are not met, remedial work on the RF cage may help to increase attenuation levels, particularly around the MR Examination room door, which is a common site for a drop in RF performance over time.

Ultimately, where RF cage performance is below specification, the local site should make an informed, documented cost-benefit decision regarding continued use, informed by MR physics advice and with clear agreement on the acceptance of any residual risk. Specific points to consider include the following.

- The occurrence of external RF interference on MR images from the current MR scanner. MR systems may be able to operate without external RF interference impacting on image quality when the RF cage is below spec. However, this may not be true for all sequences (e.g. EPI-based imaging, spectroscopy, or quantitative techniques), and the risk tolerance may differ between routine clinical imaging and advanced or research applications. In many cases the performance of the RF cage is already below spec when new MRI installations become operational (Small *et al*. 2026).

- New MR systems may be more sensitive to external RF interference. However, this working group are not aware of any examples where the existing RF cage has been used where the presence of external RF interference started after a new/upgraded system was installed.
- The replacement of an MR scanner provides an ideal opportunity to replace/work on the RF cage. However, remedial work on the RF cage is possible at any point during the lifetime of an MR system.
- The MR manufacturer may decline to provide support for any image quality problems associated with external RF interference. However, this may be the case with any MR system where the RF cage is found to be below spec.

MRI quench pipe route

At the time of writing, many MR systems require a quench pipe to vent helium gas from the MR scanner to outside of the building, with an appropriate location for the quench pipe outlet (also known as the quench pipe exhaust) to avoid individuals being exposed to the resulting plume of cold helium gas in the event of a magnet quench. The design of the quench pipe is discussed in the design stage of this guidance. However, consideration of potential routes of a quench pipe is advised early in the project to feed into the comparison of sites under consideration. Of note, there are increasing options for superconducting MR systems that operate with very little helium, sometimes described as “dry” MR systems, that do not require an MRI quench pipe.

2.6 Project delivery options

Consideration of project delivery options is recommended at this stage of the project to help with initial cost estimates. Figure 4 highlights the main differences between traditional, design & build and turnkey procurement solutions. The client must be satisfied that the preferred procurement route enables them to adequately plan, manage and monitor the project and to be satisfied of the competencies of all parties engaged in the project, all in accordance with the building regulations, building safety act, CDM regulations and any other applicable regulations. Regardless of procurement route, the Client must appoint the statutory Principal Designer roles, otherwise the Client will retain these responsibilities.

703

TRADITIONAL PROCUREMENT		
Client Appointments		
Principal Designer & Design Team	Principal Contractor	MR Manufacturer
Traditional procurement enables the client to be in full control of all appointments and they must manage the project to ensure that the design team, contractor and MR manufacturer are fully coordinated with careful attention to roles and responsibilities.		

704

DESIGN AND BUILD (D&B) PROCUREMENT		
Client Appointments		
	Principal Contractor & Principal Designer	MR Manufacturer
	Design Team	
With D&B procurement, the Principal Contractor takes responsibility for the design. It is usually recommended that the Principal Contractor is also appointed as the Principal Designer for both CDM and Building Regulations, subject to the Client's assessment of their competency to carry out those roles. The client must manage the project to ensure that the Contractors team and MR manufacturer are fully coordinated with careful attention to roles and responsibilities. It is important to note that the Client needs to be satisfied with the Principal (D&B) Contractor's choice of design team, their building contractors and their competencies.		

705 `

'TURN-KEY' PROCUREMENT		
Client Appointments		
		Turn-Key Provider is Principal Contractor and Principal Designer
	Main Building Contractor	Design Team
For 'Turn-Key' procurement, it is usually recommended that the Turn-Key provider is also appointed as the Principal Contractor and Principal Designer for both CDM and Building Regulations, subject to the Client's assessment of their competency to carry out those roles. The potential advantage is that the Turn-Key provider is the single point of responsibility. It is important to note that the Client needs to be satisfied with the turn-key operators choice of design team, their building contractors and their competencies.		

706
707 *Figure 4. Main differences between traditional, design & build and turnkey procurement solutions*

708
709
710
711

Mobile/relocatable MR scanner to provide cover during replacement MRI projects.
For replacement MRI projects, planning for the temporary installation of a mobile/relocatable MR scanner on site can be helpful to maintain some level of MRI service during the building works. In these cases, consideration should be given to matching the temporary MR scanners (make & model, RF coils, software options) to either existing or new MR scanners to minimise additional training needs for staff.

2.7 Summary & checklist

Considering all aspects of an MRI installation described above, the project team should be able to produce a shortlist of possible sites for a new MRI installation. These possible sites and the information gathered about them can now be put forward to MRI manufacturers for a technical opinion on their viability for a range of their equipment models. Ideally, different opinions would be gathered and compared. MRI manufacturers may suggest further specific tests to determine the viability of a given site (B_0 tests, vibration assessment, etc) and these tests should be undertaken prior to committing to a particular site.

After the viability of the possible sites is confirmed, including confirmation of feasible delivery routes, an initial estimate of the costs of the installation can be produced, and the first version of the business plan can be completed. Ideally, this will enable the institution to make a final decision on the chosen installation site. However, it may be desirable to progress further design and investigation work on more than one option in order to reach a more informed final decision in the next phase of the project.

Client team	✓
Included key individuals/groups within client team to ensure accurate definition of project brief?	

General clinical requirements	✓
Defined the different patient cohorts and workflows that are to be accommodated?	
Identified additional stakeholders for aspects of the project design?	
Considered potential future expansion of services to be undertaken.	

General space requirements	✓
Obtained 'golden thread' building information: power supply, water supply, structural information, fire safety information, etc?	
Defined local magnetic field threshold for B_0 Hazard Area (e.g. 0.5 mT or 0.9 mT)?	

General MR system requirements	✓
Obtained site planning guides for MR systems of potential interest?	
Checked minimum distances between the isocentres of neighbouring scanners?	
Checked distances between proposed locations and large moving metal objects, e.g. lifts, vehicles?	
Considered B_0 test to be performed to measure the levels of magnetic field fluctuation at proposed MR scanner locations?	

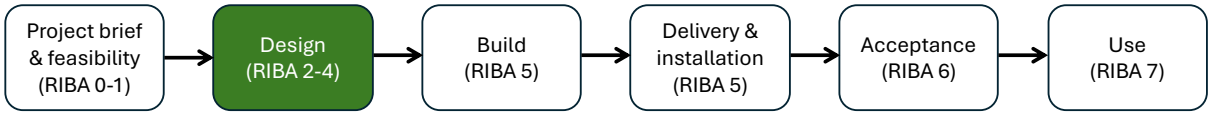
Considered the distance from proposed MR scanner locations to high voltage power lines, transformers, switches, motors, or generators, and the potential need for magnetic field shielding to avoid possible interference on MR system.?	
Considered the potential impact of the fringe static magnetic field from the MR scanner on nearby equipment sensitive to magnetic fields?	
Considered the need for magnetic shielding to limit the extent of the magnet fringe fields outside of the MR Examination room?	
Considered vibration survey of any proposed sites for a new MRI installation to establish typical levels?	
Considered structural limitations of proposed locations?	
Identified a potential delivery route for scanner and servicing (e.g. large component replacement, He supplies) for each proposed location?	
Considered the local site development control plan to identify other proposed projects that may impact on the access route during the lifetime of the MR system or for a future replacement of the scanner?	
Considered high-level options for chiller, including provision of a backup solution?	
Considered high-level options for control of temperature and humidity?	
Confirmed the maximum power requirements for potential MR systems and supporting plant can be met for proposed locations?	
Considered provision of a secondary power supply?	
Considered provision of tertiary power supplies?	
If upgrading existing MR system, considered scope to repurpose the existing RF cage, including RF attenuation measurements to establish current performance?	
Considered high-level options for the route of a potential MRI quench pipe and location of quench pipe outlet?	
Completed high level definition of the MR Controlled Access Area for each proposed location?	
Considered feasibility of each proposed location against defined general clinical requirements and relevant HBNs & HTMs?	

742
743

Project delivery options	✓
Considered project delivery options?	

744
745
746

3 Design (RIBA stages 2-4)



3.1 Introduction

This section describes the design phase of a new MRI installation project, highlighting issues that are particularly relevant to MRI that should be considered to help avoid problems during the subsequent use phase. Particular focus is made towards the following aims.

- Ensuring appropriate safety of anyone in and around the MR suite who may be exposed to the hazards associated with MR scanners.
- Improving patient experience and efficient workflows.
- Minimising MR scanner downtime.

The design section focuses on recommendations for physical design requirements but also focuses on ideal configurations to reduce the probability that a ferromagnetic object could be taken into the MR Examination room. This includes the location of different rooms as well as line of sight to safety critical areas especially from the MR control room.

Where relevant, the reader is signposted to appropriate Health Building Notes (HBNs) and Health Technical Memoranda (HTMs) published by NHS England or their equivalent versions in Wales and Scotland. Consequently, general aspects of design that are not specific to MRI are not covered here except where the context is considered important.

Other sources of information to consider for the design of new MRI installations include the following.

- American College of Radiology (ACR) manual for MRI safety, Appendix 2: MR Facility Safety Design Guidelines (ACR 2024)
- Optimization of MRI Turnaround Times Through the Use of Dockable Tables and Innovative Architectural Design Strategies (Recht *et al.* 2019)

3.2 Design team

The design team are responsible for the design of the project based upon the requirements set out in the project brief (RIBA 2020), defined previously in the Project brief & feasibility phase of the project. Professional groups such as architects, structural engineers, electrical engineers and project managers are inherently part of the design team for building projects in general, although previous experience with MRI installations for individuals in these groups can be helpful to understand the particular requirements of MRI.

Input into the design team from people with specialist knowledge about different aspects of MRI is key to ensure an optimal design and to avoid various pitfalls that can negatively impact work within the space for many years to come. Table 2 highlights some of these key individuals/groups. In certain cases, an individual may cover more than one role, e.g. the superintendent MR radiographer is often the MR Responsible Person. Importantly, clinical staff need to be allocated sufficient time to allow them to fully engage and contribute as part of the design team.

Key individuals/groups	Key roles and responsibilities in this project phase
Superintendent MR Radiographer	Radiographers are perhaps the professional group that will be most associated with working within the MR suite. Appropriate radiographer representation is key to ensure the design meets the clinical needs and supports safe and efficient workflows.
MR Responsible Person	To ensure appropriate MR Safety within the design. The MR Responsible Person is often covered by the Superintendent MR radiographer.
MR Safety Expert	To provide scientific support to the MR Responsible Person and project team on MR Safety aspects of the design. Typically, the MR Safety Expert role is covered by an MR physicist.
MR physicist	Advise on the design and equipment from an MR physics point of view. Provide MR acceptance testing.
Supporting clinical services where relevant (e.g. anaesthetics)	Provide details on requirements for supporting clinical services into the design.
PACS manager, IT personnel	To ensure any new facility meets the need of the users in communication, data management and security, access to PACS and other relevant systems.
MRI manufacturer	Although the formal tender process may not start until the end of the design phase once the full business case (FBC) has been approved, MRI manufacturers will often be able to provide valuable support at this phase of a project and their engagement is recommended as early as possible. A pre-contract services agreement (PCSA) should be considered if required. Some MR manufacturers may also offer formal design services.
RF cage manufacturer	Input into the design regarding options for the RF cage and MR Examination room door. They may also provide advice regarding magnetic shielding if required.
Magnetic shielding experts	Provision of advice regarding magnetic shielding.

Table 2. Key individuals/groups in the context of MRI that should be considered as part of the design team for new MRI installations.

It is important that the design team includes representation from all the different clinical groups that are intended to use the space, and their approval on the final design should be confirmed prior to the start of the build phase. For example, if the project brief includes scope for MRI under general anaesthesia, it is important to ensure appropriate provision and location of medical gases, suction, anaesthetic machines and that there is sufficient space to safely perform anaesthetic cases.

Ultimately, the design team should confirm the final design meets the project brief.

Real-world example: insufficient consultation and signoff by anaesthetists on the design of new MR suite

Anaesthetists were not fully consulted on the design of a new MRI installation to allow provision of anaesthetic cases resulting in insufficient space for induction/recovery to safely perform anaesthetic cases. There was no appropriate sign-off on the design from the local anaesthetic team.

Impact: No anaesthetic MRI cases were performed during lifetime of the MR system (10 years+).

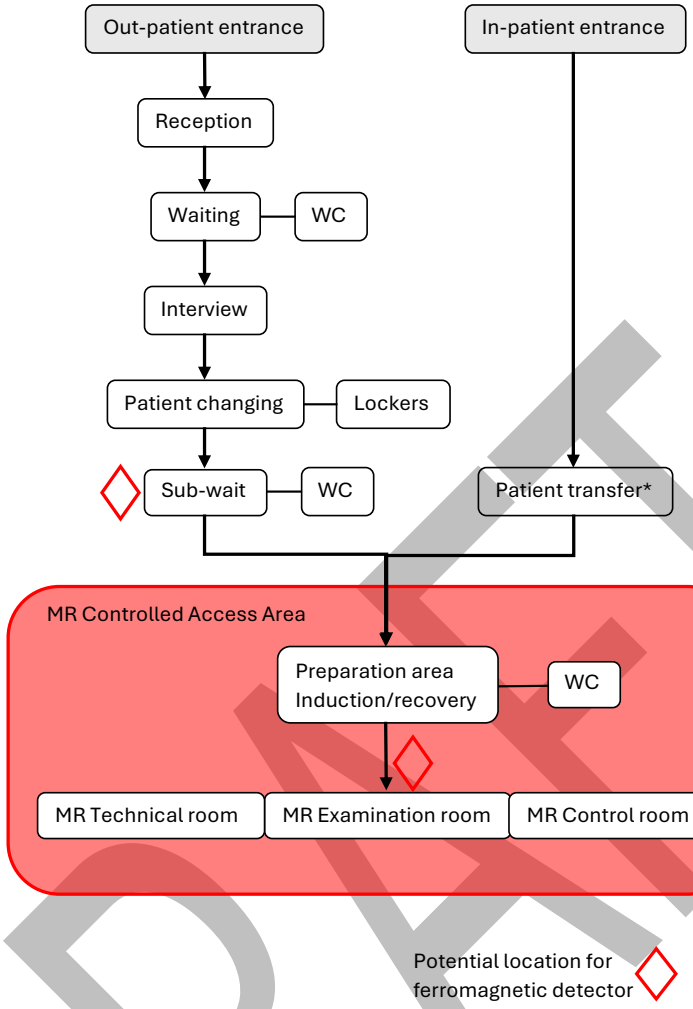
Real-world example: Multiple examples of issues concerning MR Safety and image quality, all of which were associated with a lack of an MR Safety Expert in the design team.

- The MR Controlled Access Area and access controls were not implemented for a relocatable MR suite. When the issue was realised, access controls could not be installed due to the construction of the unit, so an additional door had to be installed at the end of a new link corridor.
- The MR Controlled Access Area and access controls were not implemented for a new MR suite, with general public access into the area immediately outside the MR Examination room. A stable door was subsequently installed, but access control recognised to still be non-ideal.
- Impact of moving vehicles parking adjacent to scanner was not considered during planning. Bollards to restrict adjacent vehicle access were retrospectively installed.
- Appropriate MR Safety notices not considered.
- Lack of local MR Safety policies and procedures.

Impact: additional cost to the hospital, impaired quality of service, compromised safety and delays to clinical use

3.3 MR suite layout and general design

The layout of the overall MR suite should provide an efficient and patient-friendly experience that enhances patient, staff, visitor and public safety. Figure 5 shows an example functional workflow for patients within the MR suite. Examples of the functional relationship between different rooms and areas provided in the forthcoming HBN 06-01 guidelines, with an example provided for an MR suite supporting both out-patients and in-patient, including scope for anaesthetic cases, and a separate example for an MR suite in a hospital out-patient or community setting, without anaesthetics.



*patient transfer may occur inside the MRCAA for some designs.

Figure 5. Example MRI functional workflow diagram for the flow of patients within the MR suite. After the MRI examination, patients may spend some time within a recovery area before returning to the patient changing (out-patients) or patient transfer area.

General design options to make the space more patient-friendly should be considered. This is particularly key if looking to accommodate paediatric patients. Consideration should be given to the use of themes, murals, and natural imagery in the general decoration.

General MR Safety aspects that should be considered in the design include the following.

- Ensuring that persons with implanted/attached medical devices and other foreign bodies do not enter the MR Environment without prior safety checks and authorisation by MR staff.
- Ensuring that any other items whose function could be adversely affected by the strong static magnetic field are either kept out of the MR Environment or only permitted according to specified conditions.
- Ensuring that systems are in place to minimise the risk of ferromagnetic items being taken into the MR Environment where they could become projectiles.

Specific rooms/areas within the MR suite need to be considered are discussed further in subsequent sections.

MR Controlled Access Area

One of the important early considerations when designing an MR suite is the designation of the MR Controlled Access Area, the area which encompasses the MR Environment and to which access is controlled by suitable methods. The use of RFID-based ID badge access control allows individuals to be added/removed as required. Combination-based locks are generally discouraged as combination codes tend to become more widely distributed than originally intended. Continuous access control is important to mitigate the typically permanent risks associated with ferromagnetic objects and anyone with implanted/attached medical devices/foreign bodies who has not been MR Safety screened and approved.

All individuals, including patients, staff, and visitors, should undergo MR Safety screening prior to entering the MR Controlled Access Area, regardless of whether they plan to enter the MR Environment itself. It is advisable to confine the MR Controlled Access Area to the minimum required space to keep staff numbers to a minimum and reduce the amount of screening that needs to be performed. Typically, this area includes the MR Examination room, the MR Control Room and the areas immediately adjacent to the entrance of the MR Examination room that commonly accommodate patient preparation and recovery.

Figure 6 shows an example layout of an MR suite showing both the MR Controlled Access Area and MR Environment as well as an MR Projectile Zone. In this example the MR Environment extends into the adjacent MR Technical room. Consequently, the MR Technical room is also within the MR Controlled Access Area. This figure also highlights the four MR Safety zones, described by the ACR manual on MR Safety (ACR 2024), that some UK-based MRI installations find helpful to use. The MR Controlled Access Area is generally considered equivalent to the combination of ACR zones III and IV.

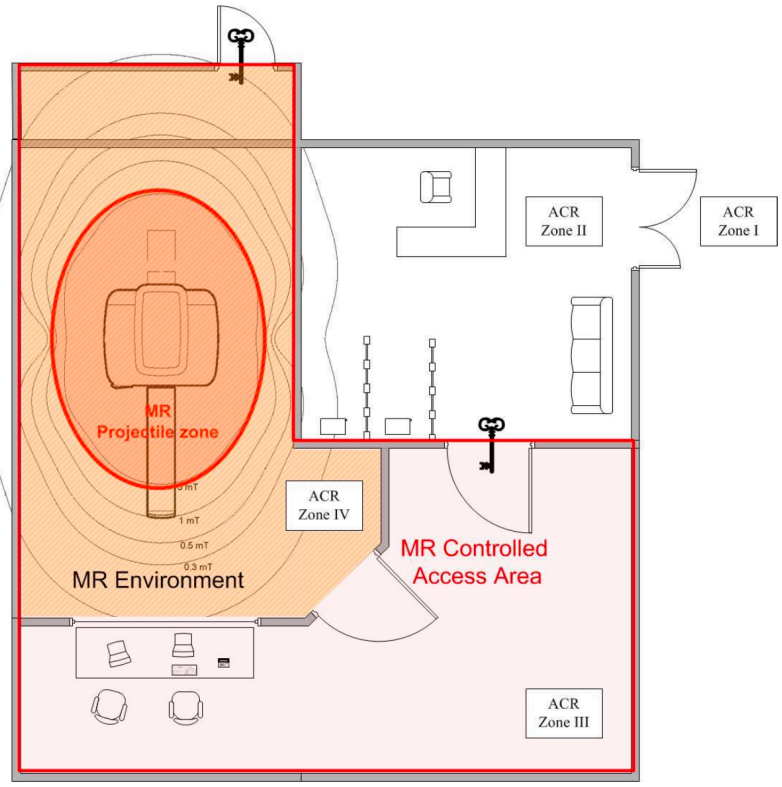


Figure 6. Example layout of an MR suite (reproduced from the MHRA guidelines with permission), showing both the MR Controlled Access Area and the MR Environment, as well as the ACR MR Safety zones.

Ideally, all patient and staff entry points to the MR Controlled Access Area should incorporate self-closing, self-locking doors, although access must be immediately available in the event of a power outage. Each entry to the MR Controlled Access Area should have warning signs on display. IPEM offer freely available MRI warning signage templates (IPEM 2017) that include examples for entry points to the MR Controlled Access Area such as that shown in Figure 7.

Figure 7. MR Controlled Access Area signage from the IPEM MRI warning signage templates.

To help with control of access, the number of entry points to the MR Controlled Access Area should be minimised. Similarly, designs where the MR Controlled Access Area could be used as a "short-cut" route to non-MRI related locations should be avoided.

For some MR suites it may be preferable to share areas outside of the MR Controlled Access Area with other modalities, e.g. shared reception, changing rooms, sub-wait. Ideally all areas within the MR Controlled Access Area should be dedicated to MRI to avoid MRI safety screening of persons for non-MRI activities and to help with control of access to the MR Environment.

Real-world example: design of MR suite did not provide any ability to define an MR Controlled Access Area.

Problems with a lack of a defined MR Controlled Access Area were not identified until after the build had started. An MR Safety Expert was not involved in the initial planning of the MR suite.

Impact: delays while stud wall removed, additional steel shielding put in place and stud wall replaced.

Fire

It is critical to understand that typically the MR Examination room, MR Technical room and MR control room form part of the functional MR system and should be considered as a single fire zone. Consequently, the separating walls, including the RF cage, RF window and RF door, are not intended

to provide any fire protection. Furthermore, the use of any fire-stopping material between these rooms will not have been tested or certified for compatibility with the cables, pipes, fibreoptics, and other interconnecting parts of the MR system, especially with regards to the potential impact it may have on them or the RF shielding capability. Consequently, any introduction of such materials would constitute a modification of the medical device, which can void the product conformity, i.e. it would no longer be authorised for medical use.

Real-world example: local decision did not recognise MR Examination room, MR Technical room and MR control room as a single fire zone.

Local decision to incorporate fire-stopping material in the conduits between the MR technical room, MR Examination room, and MR control room.

Impact: this constituted a modification of the medical device that was unauthorised by the MRI manufacturer and impacted the product conformity.

Two example layouts for fire compartmentalisation are shown below in Figure 8.

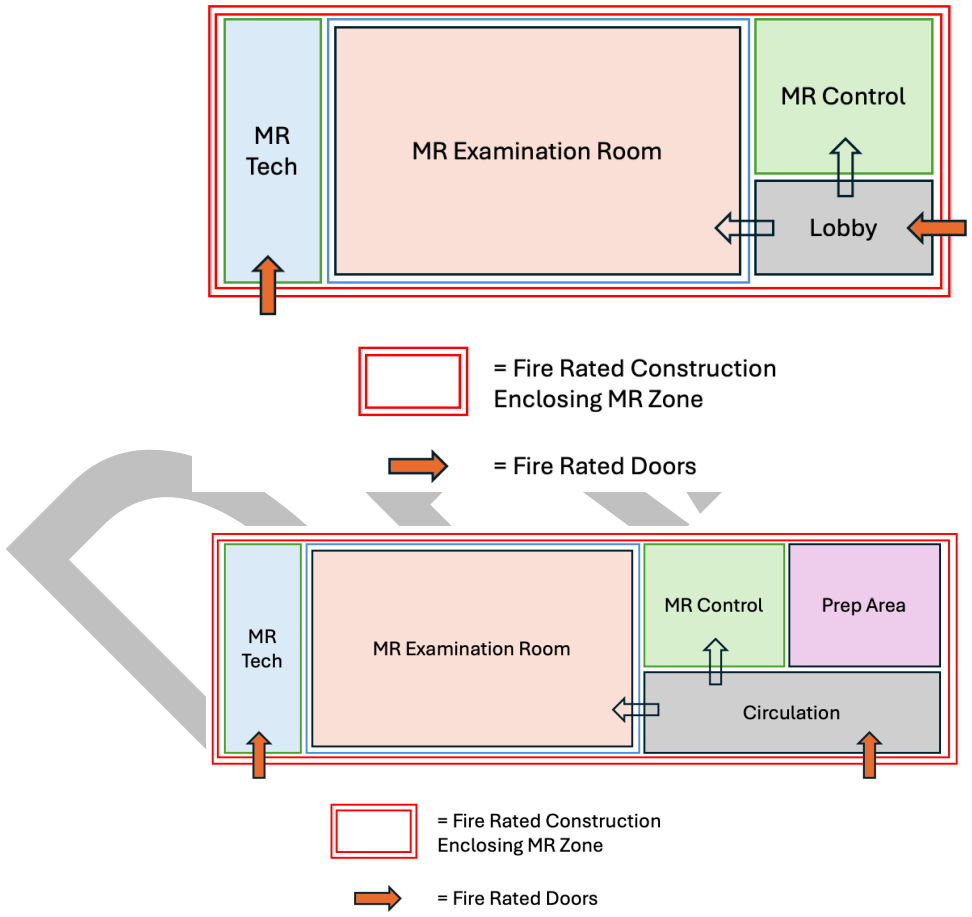


Figure 8. Two example layouts for fire compartmentalisation.

Some MR manufacturers incorporate sensitive smoke detectors within the MR system to automatically switch off power to certain components of the MR scanner. The installation of a more general-purpose smoke detector within the MR Examination room requires an appropriate connection through an RF filter panel, but this is often avoided in practice by incorporating a smoke detector within the air extract duct, outside of the RF cage.

How a general fire alarm in the hospital will impact on access control for the MR Controlled Access Area should be identified and if required, subsequent mitigations for maintaining access control should be considered.

It is important that any fire extinguishers that are intended for use within the MR Examination room are non-ferromagnetic. It is encouraged to plan for non-ferromagnetic fire extinguishers throughout the MR Controlled Access Area or MR suite to mitigate for the possibility that any of them may be used in the event of a fire in the MR Examination room.

Currently, it is uncommon to install fire sprinkler systems in MR units, although it is recognised that non-ferromagnetic water sprinkler systems intended for use within MR Examination rooms are available. Any installation of a sprinkler system in an MR unit should be a local decision, recognising that if activated, medical device certification requirements would require the affected medical device parts or the whole system to be replaced, at cost to the site. If a local decision is made to install a water sprinkler system, at least one MR manufacturer recommends the design and construction of a water sprinkler system should be made in consultation with the RF cage manufacturer to ensure that any portion of the sprinkler system penetrating the RF cage is dry until activated to avoid negatively impacting upon the RF cage performance.

Delivery route

Consideration of how any existing MR scanner will be removed and a new MR system delivered should be part of the design. MR scanners can vary significantly in weight and physical size (for details check site planning guides), and it is important that the entire proposed delivery route should be validated. Additionally, consideration should be given to maintaining an on-going route for the removal of the MR scanner when it reaches end-of-life, and the delivery of a replacement MR system.

3.4 Specific rooms/areas within the MR suite

The following rooms/areas are described in a rough chronological order of an example out-patient's journey through the MR suite. HBN 06-01 offers more general guidance, including recommendation on room sizes and example room data sheets.

Reception and waiting area

Function

Initial arrival point for out-patients. After their attendance is recorded, out-patients will typically wait in this area before being called through to next stage. Patients may be asked to read and complete an MR Safety screening form while in the waiting area, although this is dependent on local practice and it is recognised that some patients may have had an opportunity to do this prior to attendance.

Location

The reception and waiting room should be outside the MR Controlled Access Area. It may be an area that is dedicated to MR only or a shared waiting room for multiple modalities. Ideally, it should be adjacent to reception bays/check in areas, toilets and an interview room for MR staff to verify with the patient information given on the screening form. Close proximity to patient changing and preparation areas is also desirable for efficient patient pathway flows.

Operational/design considerations

The reception may be multi-service / multi-modality or dedicated to MRI only. There should be sufficient space to accommodate the expected number of patients. It may need to support in-patients as well as out-patients. Additionally, it may need to support paediatric patients.

Further considerations associated with the sub-waiting area will be relevant here if a separate sub-waiting area is not included in the design.

Pre-change preparation area

Function

To support certain patients, particularly pediatrics, by providing tools such as a toy/mock MR scanner to simulate the MRI examination and increase the patient's familiarity with the MRI experience. This can be particularly helpful for increasing patient cooperation during the MRI exam, which can be important for optimum image quality. In some cases, this can avoid the need for general anesthesia. A number of publications have highlighted the impact of play simulation in increasing the proportion of paediatric patients who are able to undergo MRI without general anaesthesia (Carter *et al.* 2010, Heales & Lloyd 2022, Anwar *et al.* 2022). One example of toy MR scanner, was reported to save a hospital £150,000 in sedation and care costs (BBC 2025). Additionally, virtual reality experiences that simulate the patient journey in MRI have also proven very useful in a paediatric setting (Stunden *et al.* 2021). This area may also function as the waiting area for paediatric patients.

Location

Generally, outside of the MR Controlled Access Area.

Operational/design considerations

Accommodate space for a play specialist, as well as space for the patient's parents/carers.

Patient screening areas / interview room

Function

A private area/room for MR staff to discuss/confirm with patients, the information declared on the patient screening form or to follow up on information. This personal information may be of a sensitive nature, and so an area that provides appropriate auditory and visual privacy is important to help encourage full disclosure any implants and other potential issues that may impact on the safety and quality of the MRI scan.

Location

This should ideally be outside the MR Controlled Access Area, between the reception/initial waiting area and the patient changing area.

Operational/design considerations

Consideration should be given to supporting electronic patient screening, e.g. availability of power and IT connections.

Patient transfer area

Function

To transfer patients who arrive in/on standard wheelchairs or patient trolleys onto MR Conditional wheelchairs/patient trolleys.

Location

Patients arriving on beds, trolleys, or wheelchairs may require transfer onto an MR Conditional trolley, an MR Conditional wheelchair, or if available, directly onto a dockable scanner table. This transfer can occur either inside or outside the MR Controlled Access Area. Selecting the most appropriate location is a key element of MR suite design, particularly for services managing patients with limited mobility or higher clinical acuity.

Patient transfer areas can require significant amounts of space. As all MR suites may have different design constraints it may be easier to site this either inside or outside the MR Controlled Access Area depending on the availability of sufficient space.

Advantages of Locating the Transfer Area Outside the MR Controlled Access Area

Reduced risk of unsafe equipment entering the controlled area

Conducting transfers outside the MR Controlled Access Area limits the presence of unsafe equipment near the controlled zone, reducing the risk of inadvertent introduction of unsafe items and lowering projectile hazard potential.

Fewer accompanying staff entering the MR Controlled Access Area

Porters, ward staff, and carers can assist with transfer without passing into the controlled area, reducing the need for MR Safety screening and supervision of additional personnel.

Disadvantages of Locating the Transfer Area Outside the MR Controlled Access Area

Additional monitoring and staffing needs

Patients transferred outside the MR Controlled Access Area may require continuous supervision, especially those at risk of deterioration. This may require increased staffing or redesign of adjacent spaces to ensure good visibility and access.

Increased movement of MR Conditional equipment

Transferring outside the MR Controlled Access Area may increase travel distances for MR Conditional trolleys or dockable tables. These devices are often heavy, less manoeuvrable, and expensive, and MRI departments may be hesitant to move them out of the controlled environment into less monitored areas.

Potential workflow inefficiencies

If MR staff must leave the MR Controlled Access Area to assist with transfer, this can reduce scanning efficiency and slow patient throughput.

Considerations for Locating the Transfer Area Inside the MR Controlled Access Area

Proximity to the MR Examination room

Locating the transfer area inside the MR Controlled Access Area minimises travel distance to the scanner, reducing the movement of MR Conditional equipment and improving workflow efficiency. However, some distance is advisable to reduce the risk of unsafe equipment being inadvertently taken into the MR Examination room.

Improved monitoring of higher-risk patients

Patients who are clinically unstable, sedated, or require close observation can be monitored more effectively if transfer occurs within the controlled environment and adjacent to MR staff.

Requirement for adequate controlled-area space

If the transfer area is placed inside the MR Controlled Access Area, the space must be large enough to accommodate beds, trolleys, equipment, accompanying staff, and safe circulation routes—all while complying with MR Safety zoning and controlled access requirements. Space within the MR Controlled Access Area is often limited, and allocating sufficient footprint for transfers may restrict other functional areas.

Summary

The decision to locate the patient transfer area inside or outside the MR Controlled Access Area depends on a balance of MR Safety, available space, patient monitoring requirements, equipment logistics, and operational efficiency. Departments with limited controlled-area space or a desire to minimise MR Controlled Access Area traffic may prefer an external transfer area, whereas services handling clinically complex patients or aiming to streamline equipment movement may favour an internal approach.

Note, patient transfer may take place on a ward if MR Conditional equipment is sent up to the ward.

Operational/design considerations

The design should consider safe storage of trolleys and wheelchairs that are unsafe for MRI, preferably outside the MR Controlled Access Area. Wheelchairs and trolleys that are unsafe for MRI present a significant hazard if left near entrances to MR Examination rooms.

Patients who require transfer from wheelchairs onto a trolley or dockable table may require the use of a hoist. Careful consideration should be given to the provision of a fixed hoist which has the advantage of unable to take into the MR Examination room and they typically can work to transfer patients directly onto MR Conditional trolleys or dockable tables. Mobile hoists have large feet for stability which may not fit under these specialist items and end up requiring multiple transfers.

Real-world example: Long feet of mobile hoist in use in an MR suite did not fit under the dockable MR table or MR Conditional trolley

Patients had to be transferred from their wheelchair to a standard MR Unlabelled trolley and subsequently from the MR Unlabelled trolley to the dockable table.

Impact: Additional time to perform patient transfer with more manual handling for MR staff.

Patient changing rooms

Function

The function of this area is for patients to be able to change from their own clothes into MR Safe clothing (e.g. scrubs or gowns) that ideally are pocketless. This ensures that there are no conductive fibres or other components within clothing (that have implications for safety and MR image artefact) and that no personal items (e.g. watches, jewellery, wallets, phones, hair grips) are brought into the MR Examination room.

Location

Ideally, the patient changing area should be located outside of the MR Controlled Access Area for the following reasons.

- Personal items and other objects that may be unsafe to take into the MR Environment are kept outside of the MR Controlled Access Area, reducing the likelihood of them being inadvertently taken into the MR Examination room.
- Reduced activity within the MR Controlled Access Area which reduces the risk of inadvertent access.

Operational/design aspects

Patients will usually be coming from safety screening to the changing area and then moving onto either a sub-wait, preparation room or directly to the MR Examination room. The changing area should be in close proximity to all these areas for efficient workflows.

Once the patient has changed, the next workflow step may be one of the following.

- The patient is taken straight through to the patient preparation area for scan preparation
- The patient is taken straight through to the MR Examination room for their scan if no preparation is required.
- The patient waits in the changing room. Careful consideration of this option should be made with regards impact on overall patient throughput, as other patients cannot get ready for their scan.
- The patient waits in a changed sub-waiting area.

The number of changing rooms should be able to accommodate the planned patient throughput. This should include consideration of potential future increases in patient throughput. Standard options for patient changing rooms should be considered, such as provision for patients in wheelchairs, a nurse call, ability to unlock and open the door outwards in the event of an emergency.

Secure storage space, e.g. lockers, should be available close to the changing area to allow patients to store their clothes and personal items while they are within the MR Controlled Access Area. Local sites should consider how they wish to manage placement of patient locker keys while the patient is undergoing their MRI scan. It may be reassuring for the patient for their locker key to stay within the MR Examination room during their scan, in which case it is helpful to consider options for non-

ferromagnetic keys, such as aluminium or brass (additionally recognising that softer metals such as brass may be less robust to physical wear and tear), or non-metal options such as RFID. Provision for master key to be held in a secure location if needed is recommended.

There should be sufficient storage space close to the changing rooms for both clean and used MR Safe clothing.

Supervision of patients should be considered. For outpatients it may be acceptable for the patients to be unattended until they are ready for their scan. Inpatients may have different needs and may need closer supervision.

Sub-waiting Area

Function

The function of the sub-waiting area is a secondary waiting area for patients who have been MR Safety screened and have changed into MR Safe clothing. This may be helpful to separate these patients from those in the general waiting area who have not yet undergone MR screening and changed into MR Safe clothing.

For some patients, the sub-waiting area may also function as a location where they drink an oral preparation prior to their MRI scan.

Location

Ideally, the sub-waiting area should be located outside of the MR Controlled Access Area to help reduce the patient's time within the MR Controlled Access Area and the associated level of supervision by MR staff that is required. In some cases, the initial waiting area may also serve as the sub-waiting area.

The sub-waiting may be adjacent to the entrance to the MR Controlled Access Area and the preparation area within, as this follows the patient pathway and it is more efficient for staff.

Operational/design considerations

If a separate sub-waiting area is not included in the design then these consideration should form part of the section for the patient waiting area.

Access to toilets within/close to the sub-wait area should be considered, particularly if intended MRI service includes examinations that may necessitate patients emptying their bladder/bowels before/immediately after their scan.

The area should incorporate scope for patients in wheelchairs.

Ferromagnetic detection systems are intended as ancillary screening devices and are not intended to be used as a replacement for traditional safety programmes, training or primary screening methods but as a complimentary tool. If a local decision is made to install a ferromagnetic detection system, then the sub-waiting area is one location where this can be located. Here, it can serve as an additional check for any ferromagnetic items before taking a person into the MR Controlled Access Area. An alternative location for a ferromagnetic detection system is at the MR Examination room door, where it can help support a check for ferromagnetic items as a person enters the MR Examination room. Local MR staff will likely be best placed to define the optimum location based on established work procedures and planned patient workflows. A key point to consider is the scope for alarm fatigue, where MR staff become desensitised to the alarm as a result of frequent alarm alerts.

Patient preparation area

Function

The primary purpose of this area is the final preparation of the patient before they enter the MR Examination room. This will include functions such as cannula insertion, but may also include sedation / anaesthetic induction.

If there is no separate recovery area then the patient preparation area will also function as a location for the patient to recover after their MRI exam. This may include any patients having drug reactions, e.g. to MRI contrast media. Additionally, the area may need to provide a location for the crash team to come to perform emergency resuscitation procedures, outside of the MR Environment.

If there is no dedicated patient transfer space outside of the MR Controlled Access Area then the preparation area may also need to provide a space for transfers to take place from standard equipment that is typically unsafe for MRI to MR Safe/MR Conditional alternatives. Such equipment may include wheelchairs, hospital bed, patient monitoring, infusion pumps, anaesthetic machine and oxygen cylinders. Additionally, the space may then provide a location for the MR Safety screening of in-patients. Finally, the space may need to act as a 'holding area' whilst an in-patient is waiting to return to the ward.

Location

The preparation area is typically located within the MR Controlled Access Area, near to the MR Examination room, as it usually forms the step in the patient pathway immediately pre/post MRI scan.

Operational/design considerations

The area should include space to support a sufficient number of cannulation chairs. The size of the area and its position in relation to the MR Examination room door should allow for easy manoeuvring of an MR Conditional trolley or dockable MR table in/out of the MR Examination room. Even if the site is planning only to scan ambulatory out-patients, this may be relevant to support safe evacuation of patients from the MR Examination room when required.

How patients within the preparation area will be medically supervised should be considered. In many cases, having the preparation area observable from the MR Control room is preferable to support this.

When considering access and size especially with respect to anaesthetic cases, any room used for anaesthetic induction may need to be able to accommodate:

- a bed or standard trolley as MR Conditional trollies may not meet the requirements for anaesthesia (e.g. they do not tip head down).
- carers and parents of children or patients with learning disabilities may need to be able to come into the preparation room for anaesthetic induction.
- provision of additional procedures (e.g. dental care for severe learning disabled patients, lumber punctures/biopsies) which may require additional room for staff and equipment to carry out these procedures.
- Space for access to resuscitation and difficult airway equipment.
- Lockable drug cupboards.

Provision of medical gases may be required. If anaesthetic cases are planned, input into the design of the preparation area from the local anaesthetic team and eventual sign off is strongly recommended.

To help with control of access, accommodating an additional WC within the MR Controlled Access Area may be helpful to avoid MR Safety screened patients having to temporarily exit the MR Controlled Access Area.

MR Examination room

It is particularly important to ensure the design of the MR Examination room is as complete as possible since subsequent changes may require the magnet to be temporarily ramped down, which is both costly and extends MR scanner downtime.

For replacement MR systems, the design requirements will depend on the level of alterations that are planned. However, even with minimal changes, it is important that MR staff are fully engaged in the design process to help ensure that important details are not missed.

Real-world example: reinstallation of anaesthetic gases was missed when new RF cage was installed as part of a replacement MRI installation

It was wrongly assumed that the existing provision of anaesthetic gases would be reinstated when a new RF cage was installed as part of a replacement MRI project.

Impact: Initial MRI anaesthetic cases delayed by several weeks. MR scanner was down for one day to retrofit anaesthetic gases with additional cost to the hospital.

Function

The MR Examination room is where MR scanning occurs, but this may also include different aspects depending on the MRI services that are to be provided. This may include the following.

- Administration of MRI contrast agent and other drugs
- Interventional activities (e.g. biopsy)
- Transfer of the patient onto and off the scanner couch.

In addition to the MR scanner, the room needs to various other equipment according to the particular MRI services that are to be provided.

Location

The MR Examination room is located next to the MR Control room and typically immediately adjacent to the MR Technical room and patient preparation/recovery area. The MR Examination room is part of the MR Environment, and is therefore located within the MR Controlled Access Area.

The entrance and approaches to the MR Examination room will ideally be visible from the MR control room. This is to allow MR staff within the MR Control room to observe whether anyone is unexpectedly attempting to access the MR Examination room. Similarly, incorporating some distance in the design between the entrance to the MR Examination room and entrance to the MR Controlled Access Area is desirable to help to mitigate the risk of an unauthorised person entering the MR Examination room if they manage to gain access to the MR Controlled Access Area, e.g. via tailgating another individual.

Importantly, the MR Examination room needs to be located such that the position of the MR scanner within the room meets the MR manufacturers specification regarding minimum distances from the isocentre of the MR scanner to various items that may negatively impact MR quality, which may include the following.

- Steel within the building
- High-voltage power cables
- Other MR systems. In general, designs where multiple MR scanners are orientated in parallel provides scope for minimum separation distances.
- Large moving ferromagnetic objects, e.g. motor vehicles, lifts

Additionally, the potential for neighbouring equipment sensitive to magnetic fields, e.g. gamma cameras, to be adversely impacted from the MRI fringe magnetic field should be considered.

Operational/design considerations

The MR Examination room must be large enough, and arranged appropriately, to enable safe and efficient transfer of all patients—including those walking or arriving on MR Conditional beds, trolleys, or wheelchairs—both into the room and onto/off the MR scanner table. The room layout, entrance location, and scanner orientation should all facilitate smooth patient flow and allow for rapid patient evacuation in the event of an emergency. Space must also be sufficient for transferring any MR Conditional equipment intended to enter the room, such as an anaesthetic machine or power injector. While manufacturers may provide minimum room-size specifications, these often focus solely on accommodating their scanner and associated hardware. It is therefore essential to consider broader clinical requirements, emergency planning, and the specific MRI services to be delivered when determining the appropriate room size. Storage and operational space for emergency evacuation equipment (e.g., evacuation trolleys) should also be planned within the room layout.

Additionally, consideration should be given to any additional equipment that will be required temporarily/permanently within the MR Examination room to support the intended MR services. This equipment may include the following.

- MR Conditional power injector
- MR Conditional anaesthetic machine
- MR Conditional patient monitoring
- MR Conditional patient video system
- Additional equipment not included as standard e.g. display units for fMRI visual stimulation
- MR-guided biopsy equipment
- Specialised MR procedures e.g. MR-guided focussed ultrasound.
- Radiotherapy planning lasers

HBN 06-01 has general recommendations about scanner positioning to allow clear views along the magnet bore, MR Examination room door location, provision of area next to the table for patient transfer, provision of a relaxing and distracting patient environment, fixtures and fittings, soundproofing, minimum room sizes. It also recommends that it is adjacent to the control room and technical room.

Real-world example: insufficient space at the rear of the MR scanner to allow the MR table to move out to full extent

Design did not account for extended MR tabletop motion that was provided for whole body MR applications.

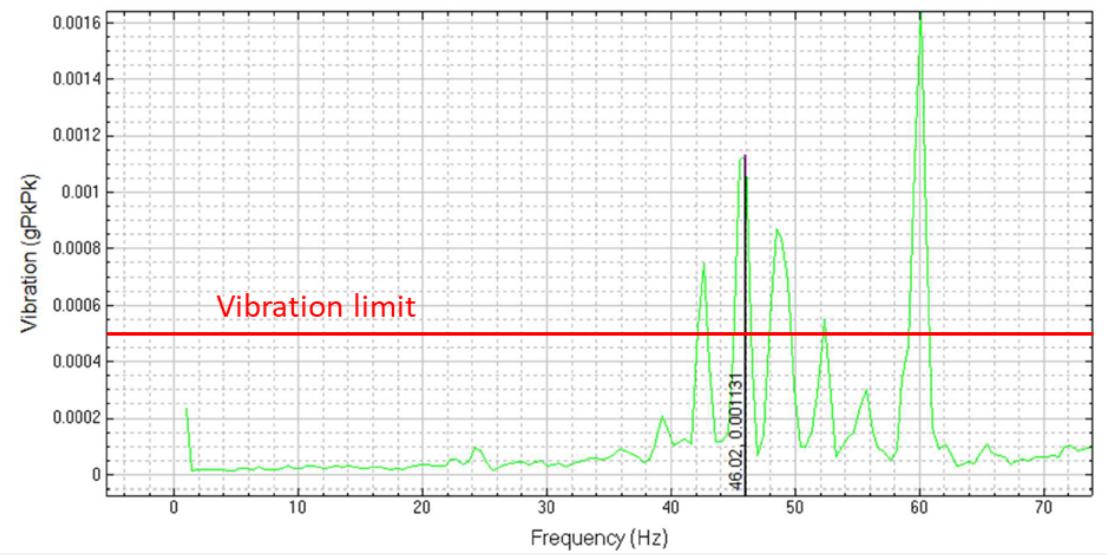
Impact: MR scanner had limited scope to perform whole-body MRI studies for the duration of the MR system (10 years+).

Anti-vibration pads

Even if building vibration levels are within limits at the time of installation, incorporating use of anti-vibration pads helps to mitigate for future vibration problems that might arise from the nearby installation of other equipment during the lifetime of the MR system. Additionally, anti-vibration

pads may help to reduce the acoustic impact from the MR scanner to neighbouring areas via structure-borne noise transmission. MR manufacturers typically provide specifications for anti-vibration pads to be used for their systems.

Real-world example: new plant equipment installed close to MR suite creating vibrations that exceeded MR manufacturer's specifications



The vibration created by the equipment exceeded the specification limit defined by the MR manufacturer.

Impact: No known impact on MR scanner in this case, but it was recognised that the MR scanner was installed on anti-vibration pads.

RF cage

Typically, the MR Examination room needs to be enclosed within an RF cage (also known as a Faraday cage or RF cabin) to shield the MR scanner from external radiofrequency signals originating from outside the MR Examination room that can otherwise impact on image quality. The RF cage also serves to attenuate the RF signals emitted by the MR scanner being transmitted beyond the MR Examination room. The MR manufacturer will specify the required shielding effectiveness. Typically, this is between 90-100 dB at several specified radiofrequencies. If scope for multi-nuclear MR systems is to be included, then consideration of testing at additional relevant frequencies may be appropriate, particularly after all installation work has completed.

Real-world example: Equipment producing RF interference at 31P frequencies

A third-party piece of equipment that was intended to be used in conjunction with 3T MR systems was found to produce RF interference at 31P frequencies at 3T.

Impact: The screen was not used during 31P-MR exams, preventing the acquisition of some planned studies.

It is important that all requirements from RF cage manufacturer are incorporated into the design. Typical requirements for the concrete slab supporting the RF cage include the following

- Depth. It is often important to ensure a consistent floor level between the MR Examination room and immediately outside the room, recognising that even relatively small physical bumps can be unacceptable for wheeling certain patients in/out of the MR Examination room. To achieve this, the concrete slab underneath the RF cage should be cast/scabbled to accommodate the cross-section of the RF cage the MR Examination room door, as specified by the RF cage manufacturer. Alternatively, feathering of the floor immediately outside of the MR Examination room to raise the height as it approaches the MR Examination room may be possible, although subsequent implications of a non-level floor for patient trolleys and other wheeled equipment should be considered.
- Flatness. Typically, RF cage manufacturers have requirements on the flatness of the concrete slab that are often stricter than many other building projects. Additional self-levelling compound may be required to meet the required specification.
- Dryness. Prior to installing the RF cage, the concrete slab should be sufficiently cured to support the weight of the MR scanner, since the first step of the RF cage build often involved laying down a moisture barrier that may restrict further drying of the slab.

Real-world example: change in floor level when entering the MR Examination room door

The change in floor level caused a "bump" when wheeling patients in/out of the MR Examination room that was significantly problematic for patients with spinal problems.

Impact: A slope to avoid bump was retrofitted at additional expense and time

Real-world example: setting of lower floor level for MR Examination room did not take into account the MR Examination room door frame

While the floor of the MR Examination room was equal to the floor level outside, the reduction in the slab level did not extend to the MR Examination room door, resulting in a sizeable change in level at the door threshold.

Impact: A slope to avoid bump was retrofitted at additional expense and time

Some aspects of the RF cage design are specific the make and model of MR scanner which is to be installed. Examples of this include the penetration panel and floor anchoring points. Consequently, delaying the build of the RF cage until selection of the MR system helps to avoid separate follow up work on the RF cage. Additionally, it is important to plan for the RF cage build to start once as much of the main building works have completed. Delivery of the RF cage materials before the project is ready may result in additional challenges for the secure storage of materials and an increased risk of damage.

Different materials can be used for the RF cage, with copper, aluminium and steel being the main examples. Copper has an advantage over aluminium and steel of being able to adapt on site to any unexpected deviations from plans. Additionally, it may be helpful to support future adaptions to the RF cage. At the time of writing at least one of the major MR manufacturers recommends the use of copper as the preferred material for the RF cage suggesting effectiveness, long term stability, design possibilities, manufacturing, customising and costs. RF cages made from aluminium require additional care during construction, particularly around doors and windows, to ensure sufficient electrical contact between panels due to the layer of aluminium oxide that may otherwise negatively impact on the level of RF attenuation. Steel is also an option for RF cages, although MR manufacturers may specify additional requirements, such as the use of non-ferromagnetic material

immediately underneath the MR scanner. Further details can be found in the MR manufacturers site planning guides.

Real-world example: external wall was not sufficiently weatherproof before RF cage was built

During a period of stormy weather water penetrated the building, came down internal walls and under the RF cage.

Impact: The RF cage, along with the internal walls and floor, had to be replaced, resulting in a two-month project delay with associated significant costs for the hospital that included outsourcing of MRI scanning.

Any electrically conducting connection through the RF cage (e.g. electrical supply for lighting, power sockets, network cable) must pass through an RF filter, while any non-electrically conducting connection through the RF cage can pass through a waveguide. There is scope to use media convertors to modify conducting signalling cables, e.g. ethernet cabling, into non-electrically conducting fibre-optic cable, thereby allowing it to pass through an RF waveguide. However, electrical filters for ethernet connections are also available. If general anaesthesia of patients is to be performed it is essential to install RF waveguides through the RF cabin for suction, oxygen, medical air, anaesthetic gases, and an anaesthetic gas scavenging system.

The location and dimensions of waveguides should be confirmed with the intended users. This should attention to the height of planned waveguides, particularly into the MR Control room where it may be helpful to locate both above and below worktop level to support a range of connections.

Real-world example: no waveguide between MR Examination room and control room.

A new MR unit was installed without any waveguides between the MR Examination room and the MR control room.

Impact: impaired ability for optical fibre connections between MR Examination room and the MR control room, e.g., for patient monitoring, power injector.

Larger diameter waveguides may be required, e.g. to allow projection of images/video from outside of the MR Examination room, or to allow items to be passed into the MR Examination room for particular MRI cases. Consideration should be given to waveguide solutions as part of the MR Examination room door that allow placement of non-conducting lines without needing to disconnect these from the patient.

Real-world example: size of installed waveguide was insufficient for intended use

Size of installed waveguide was found to be insufficient to allow pass through of items required for general anaesthetic cases.

Impact: Wider waveguide was retrofitted at additional cost. 2 days downtime

Although uncommon, should a local decision be made to install a fire sprinkler system within the MR Examination room, sprinkler systems that avoid hold the water outside of the RF cage should be used. Non-ferromagnetic water sprinkler systems intended for use within MR Examination rooms are available. RF cage manufacturers may be able to advise further on suitable designs.

A removable conducting plate within the RF cage, known as a penetration panel or filter panel, can be used to accommodate multiple RF filters/waveguides. Use of softer metals, such as brass, for the penetration panel can be helpful practically if there is a need to add additional connections in the penetration panel after it has been installed. Installation of a blank plate may be helpful as part of futureproofing.

A penetration panel will be installed for the MR manufacturer to make connections between the MR scanner and their equipment in the MR Technical room. Ideally, this MR system penetration panel should be dedicated to connections made by the MR manufacturer only. One or more additional penetration panel should be installed to support other connections into the RF cage that are not directly associated with the MR system. The distance between the MR system penetration panel and other penetration panels should meet any minimum distance requirements specified by the MR manufacturer. Additionally, a minimum clearance on both sides of the filter panel should be specified for servicing/future modifications.

Air ducts connect into the RF cage via separate honeycomb waveguides. The ceiling of the RF cage should incorporate a typically 600x600 mm honeycomb wave guide, providing an air connection from the MR Examination room to the void immediately above the RF cage that provides some ability for air pressure equalisation when the MR Examination room door is opened/closed.

To further avoid the potential for RF interference to be transmitted into the MR Examination room, it is important for the RF cage and all electrical items within it to be connected to a common electrical earth. The RF cage must be connected to a single RF common electrical ground stud which is also the earthing connection for the MR system power distribution unit supporting the gradient and RF system cabinets in the MR Technical room. This ensures a common earth between all parts of the system. Typically, a separate earth reference point is required for each MR system. Further details should be available in the MR manufacturer's site planning guide.

To ensure electrical isolation between honeycomb waveguides in the RF cage and external air ducting, a non-conducting packing material, e.g. wood, should be used, as shown below in Figure 9. Mechanical vibration is known to be another potential source of RF interference. Consequently, a degree of mechanical isolation between the RF cage and any attached structures (e.g. ducting, pipes) is desirable to reduce the possibility of vibrations being transmitted onto and into the RF cage.

Figure 9. Example of wooden frame providing electrical isolation between honeycomb waveguides in the RF cage and external air ducting.

If an existing MR scanner is being replaced and it has been established in the pre-design phase that the performance of the existing RF cage is sufficient (perhaps with localised remedial work if required) then repurposing the existing RF cage can reduce costs. This option also provides scope to plan for the old MR scanner to be removed immediately prior to the delivery of the new MR system, utilising the same exit/delivery route including scaffolding, creation of MRI entry/exit panels, propping and ramps. It is important to note that there may be substantial delays and costs associated with a late decision to procure and install a new RF cabin.

Real-world example: An existing RF cage was initially considered to be sufficient for a replacement MRI installation, but the performance was subsequently found to be insufficient during the build phase of the project.

A new RF cage was purchased and installed.

Impact: Additional 3 weeks to project + additional £200K costs

MR Examination room door

Unless there are other requirements, there is usually only a single door into and out of the MR Examination room. This should be lockable to prevent inadvertent access when the MR suite is unattended. However, this door should always be openable from within the MR Examination room.

The MR Examination room door should have clear signage indicating the hazards in the MR Examination room. Immediately outside of the MR Examination room door it is helpful to incorporate floor signage to highlight that the magnetic field is always on, as well as a retractable belt barrier that can be used to further provide access control as required. A mains-powered illuminated “The magnet is always on” sign with integrated battery backup may be placed above the

MR Examination room door, although consideration should be made for an appropriate schedule for preventative maintenance. Examples of all of these are shown below in Figure 10.

Figure 10. IPEM door and floor warning signs (IPEM 2017) and an example of both in practice, additionally demonstrating a second copy of signage on the inside of the door to maintain a visible warning sign when the door is open

For MR scanners with a quench pipe, in the unlikely event of both a magnet quench and a quench pipe failure, large amounts of helium gas may be emitted into the MR Examination room over a short period of time (typically, 10s of seconds). This will greatly increase the room air pressure and subsequently prevent opening of the door if it opens inwards into the MR Examination room. An emergency air extract system, discussed later in the Air Handling section, is typically insufficient on its own to remove the large amounts of helium gas from a full quench for an MR system containing many 100s of litres of liquid helium in a timely manner to avoid room over-pressure and allow immediate access to the MR Examination room. Various mitigation options to consider for this scenario include the following.

- An outwardly opening MR Examination room door.
- An outwardly opening hatch within the MR Examination room door or elsewhere within the wall of the RF cage.
- An alternative over-pressure relief mechanism.

The door into the MR Examination room forms part of the RF cage. The RF seal may result in greater resistance to opening/closing and therefore consideration should be made to ways to aid manual handling, both in the initial design and subsequently with regards ongoing maintenance during the use phase.

There have been several examples of MR Examination room door failures where the lock on the MR Examination room door has failed, preventing MR staff from accessing the patient (Steckner *et al.* 2026), many of which have been reported as adverse incidents. The size and specialist nature of the magnet room door make door failure more difficult to rectify. Importantly, some RF cage manufacturers provide backup options to open the door in these scenarios and requests for clarification on this are recommended to feed into the design. Where these are not available, sites should consider further mitigation options, such as the following.

- As a result of the RF contact fingers around the edge of the door, the force required to pull the door open can be considerable. A magnet room door design where the handle to pull the door open is physically separate from the door locking mechanism may help to reduce wear and tear, and ultimately failure of the door locking mechanism.
- A second door into the MR Examination room provides additional mitigation for failure of the main magnet room door. The advantages of a second magnet room door are that it provides an alternative entrance / exit. The disadvantages are that additional control measures will be required to ensure no inadvertent access into the MR Examination room, the increased expense and the requirement for sufficient space to accommodate this design feature. A possible solution to inadvertent access would be to require the second MR Examination room door to be locked at all times and only unlocked in an emergency situation. It should be noted that having a second magnet room door may increase maintenance costs.

Real-world example: MR Examination room door latch failure

A radiographer found the MR Examination room door would not open, preventing them from gaining access to the patient in the scanner. After various unsuccessful attempts were made to open the door, including the patient attempting to open the door from the inside, the fire rescue services were called in and a decision was made for them to break and remove a window into the MR Examination room, through which the patient was rescued (see photo). Fortunately, the patient was able to remove themselves from the MR scanner and stayed calm throughout the 3 hours before they were rescued.

Subsequently, the door manufacturer replaced the door with another that included a removable panel that allowed access to the door latch mechanism should a similar event occur (see photo). Additionally, they replaced the door latch with a roller-ball latch.

Impact: 7 days of MR scanner downtime, about £20K cost to hospital

Magnetic shielding

In addition to RF shielding, there is scope to install high magnetic permeability metal shielding within the walls/floor/ceiling of the MR Examination room. Typically, the main objective for this magnetic shielding (sometimes described as passive shielding) is to limit the extent of the B_0 Hazard Area to the MR Examination room, particularly if the adjacent area is publicly accessible. Such shielding is often required for higher field MR systems, e.g. 3T, particularly if the building has a floor immediately below the MR scanner. Additionally, magnetic shielding can be used to reduce to likelihood of nearby large moving metal objects, such as motor vehicles and lifts, negatively impacting MR image quality (via temporary disturbances to static field homogeneity) if the minimum distances from these objects to the proposed position of the MR scanner, as specified by the MR manufacturer, cannot be met.

To establish whether magnetic shielding may be required, MR manufacturers provide information in their site planning guides about the spatial extent of the static magnetic field around their MR systems. This can be overlaid on room plans to give an initial indication of the extent magnetic field contours, although importantly the actual distributions may vary due to metal in the structure of the building around the MR Examination room, in particular the location of steel beams. Simulations to take these into account and calculate more accurate distributions can be performed by the MR manufacturers. Consequently, it is important to identify any existing steel in the vicinity of the MR Examination room to support these more accurate calculations. Subsequently, such simulations can be used to calculating the amount of magnetic shielding that is required to restrict the extent of the B_0 Hazard Area accordingly. Importantly, these predictions will be based on the ferrous metal used for the shielding. Examples include M36 silicon steel, Armco and Stabolec steel. In instances where a different material to that used in the simulations is desirable, e.g. to better accommodate structural needs, this should be checked with the MR manufacturer. In some cases, updated simulations may be required.

In the scenario where a decision on the magnetic shielding is required before a decision on the MR scanner to be installed, simulations may be performed by other bodies, e.g. RF cage manufacturers, based on a known worst-case example.

Real-world example: B_0 Hazard Area extension into main hospital corridor following inaccurate magnetic shielding calculations.

This was attributed to steel within the building that was not taken into account in the magnetic shielding calculations. The extension of the B_0 Hazard Area into the main hospital corridor exposed patients and staff to hazards associated with the static magnetic field.

Impact: Additional shielding installed at cost to hospital, 1 month delay to project

Real-world example: the B_0 Hazard Area extended further out of the building than predicted.

The original calculations of the fringe field did not consider metal cladding on the building which pushed the fringe field out in areas without cladding.

Impact: delays while stud wall removed, additional steel shielding put in place and stud wall replaced.

Real-world example: the B_0 Hazard Area extended further out of the building than predicted.

The original calculations of the fringe field did not consider existing metal plate in the floor which pushed the fringe field out in neighbouring areas.

Impact: additional work required to corridor to avoid public access to B_0 Hazard Area.

The amount of magnetic shielding can vary in size, from a small plate on a single wall to multiple layers on all walls, the ceiling and floor, with weight varying according from a few hundred to thousands of kilograms. Consequently, magnetic shielding may be significant in terms of structural support and therefore reconfirmation of structural support for any magnetic shielding is recommended. Additionally, the MR manufacturer will specify limits on the size of magnetic shielding that can be used in relation to the distance of the shielding from the MR scanner. If magnetic shielding is required underneath the MR scanner then there may be scope to suspend this from the slab into the ceiling void of the floor below to increase the distance to the MR scanner isocentre.

Acoustic noise

MR scanners can generate significant amounts of acoustic noise. Additionally, equipment in the MR Technical Room may also be acoustically loud. Acoustic noise issues should be considered, particularly if there are noise-sensitive locations near to the MR suite. These locations include wards, office space and operating theatres but may include other areas. Sensitivity to acoustic noise is likely to be more of an issue for a new MR suite, where people in neighbouring areas are unfamiliar to the background sounds of MRI scanning. Additionally, acoustic noise within the MR suite should be considered. One of the potential disadvantages of MR suite designs where the MR Examination room opens directly into the MR control room is increased noise levels in the MR control room.

Noise transfer can be airborne or via the building structure. Positioning the MR scanner on anti-vibration pads within the MR Examination room may help to reduce structure-borne noise transmission, in addition to vibration issues. The use of acoustic foam/panels either side of the RF cage as well as sound-insulating plasterboard may help reduce noise transmission to adjacent areas. Similarly, the introduction of non-conducting packing material into RF waveguides may be helpful to support reduced transmission of acoustic noise. The use of passive acoustic screening within the MR Examination room has also been reported (Moelker et al 2003).

To address acoustic risks and advise the design team the client should consider appointing an acoustic engineer to advise and potentially perform/specify requirements for an acoustic noise survey. More general guidance on acoustic noise considerations is provided in Health Technical Memorandum 08-01: Acoustics (NHSE 2013). Site planning guides may describe options for acoustic noise suppression and some RF cage manufacturers offer options for this as part of their product.

Patient privacy

Depending on the types of MRI examinations planned, the use of blinds or switchable smart glass should be considered with any windows into the MR Examination room to ensure patient privacy.

Lighting

In addition to lower power requirements, LED-based lighting offers the benefit of longevity compared to incandescent lamps. Additionally, conventional filament lamps on an AC supply in the immediate vicinity of the magnet will experience oscillating forces that further reduce their longevity. However, general LED lighting, where the conversion from AC mains to DC occurs within the lamp unit, can cause RF interference that negatively impacts on MRI image quality. Lighting in the MR Examination room should be provided by direct current (DC) LED fittings, certified as suitable for use in the MR Examination room.

Real-world example: original LED lighting installed in MR Examination room caused artefact on MR images

Standard LED lighting that was not specifically designed to be compatible with MRI was installed. The AC/DC conversion that occurred at each lamp produced RF interference that was picked up by the MR scanner, impacting image quality.

Impact: Costs and delay required to retrofit appropriate LED lighting.

Consideration should be given to the required lux levels in all areas within the MR suite including the MR Examination room, particularly if planned MRI services include items where increased illumination is important such as injection and biopsy. HBN 06-01 does not provide specific guidance on lux levels, instead signposting to Lighting for healthcare premises guidelines from the Chartered Institution of Building Services Engineers (CIBSE 2019). This CIBSE guidance has recommendations for both 300 lux and 500 lux for MRI imaging suites. The higher figure of 500 lux is recommended here as a minimum, particularly if there is an intention to perform injections, biopsies or other interventions within the MR Examination room, with an option to dim the lighting if required, e.g. to support feed and wrap neonatal MRI. Colour controllable LEDs for mood-enhancing lighting to enable an improved patient experience may be considered. Emergency lighting in the event of a power failure is a requirement under BS 5266-1 (2025), with the level of emergency lighting determined by local requirements.

Ideally, the light switch for the MR Examination room should be located outside of the room, e.g. in the MR Control room, to provide the ability to illuminate the MR Examination room without entering. This allows a visual inspection via the MR Control room window while maintaining a locked MR Examination room door which may be preferable in the event of an alarm going off out of hours.

Real-world example: Fire alarm in MR suite out of hours

The fire alarm was triggered in the MR suite in the middle of the night. The attending fire brigade wanted to illuminate the MR Examination room to visually check for signs of smoke, but the light switch was located in the MR Examination room.

Impact: MR staff were called to site to gain access to the MR Examination room to turn on light. Subsequent new MRI installations designed with MR Examination room light switch located in the MR control room.

Finally, artificial skylights or illuminated wall panels should be considered to improve the patient experience, although again these should be designed to work in an MR Examination room without causing RF interference. An example of such a skylight is shown below in Figure 11.

Figure 11. Example of artificial skylight designed for use in the MR Examination room that may be considered to improve the patient experience of an MRI scan.

Patient experience

Various options are available for consideration within the MR Examination room to help improve patient experience. Importantly, such measures can help improve patient co-operation during the MRI scan, particularly with regards staying still, which subsequently has an impact on the quality of the MR image acquired. This may be more relevant for certain patients, e.g. individuals who are particularly anxious and paediatrics.

In addition to artificial skylights and illuminated wall panels mentioned above, a video system that allows patients to watch videos during their MRI scan can be helpful in multiple situations. If such a system is incorporated into the design of the MR Examination room, then it will need to be located behind the MR scanner, level with the scanner bore for the patient to view. Ideally, it will be mounted to the wall, but there is scope to have systems mounted on a floor stand. Such video systems require additional space within the MR Control room for the video control.

Floor demarcation and tether anchor points

Consideration should be given to marking a zone within the MR Examination room using a change in floor colour or a visible line. This can be helpful to demarcate a specific static magnetic field strength around the MR scanner. The chosen field strength typically serves one of two purposes:

- To indicate where certain MR Conditional equipment—which has limits on the maximum static magnetic field it can safely be exposed to—should be excluded from. An IPEM report on MRI safety signage (IPEM 2017) indicates a 10 mT floor marking is appropriate for most MR Conditional equipment that may be brought into the room.
- To define the extent of a local MR Projectile Zone, if such a zone is designated based on local risk assessment.

An example of floor demarcation is shown below in Figure 12.

Figure 12. Example of change in floor colour to demarcate the MR Projectile Zone close to the MR scanner and a tethered anaesthetic machine

Additionally, the fitting of anchor points in the walls inside the MR Examination room with fixed-length tethers should be considered to help ensure such MR Conditional equipment is not inadvertently moved closer to the MR scanner and into a higher magnetic field than is specified on the MR Conditional labelling. The fitting of these and any other wall fixations must be carefully planned to avoid inadvertently penetrating the RF cage. An example of wall anchor points is shown below in Figure 13.

Figure 13. Example of anchor point in wall providing scope for non-ferromagnetic chain to tether an MR Conditional anaesthetic machine to avoid it being taking closer to the MR scanner than intended.

Storage

Provision of adequate storage within the MR Examination room is essential to accommodate various MRI equipment and consumables. It is important to consider standard manual handling, which can be particularly relevant for heavier items such as some MRI coils and test objects. The MR manufacturer may provide a coil storage cart as part of the MR system, but additional storage will be likely.

Real-world example: high shelving for MRI test objects

Manual handling was not considered as part of the design and high shelving was installed for the storage of heavy MRI test objects.

Impact: Ongoing manual handling issues for MR staff and potentially increased risk of droppage.

Power sockets/network ports

The need for power sockets and network ports within the MR Examination room should be considered. Any power and network cabling connections into the MR Examination room will be required to pass through filters to avoid introducing unwanted external RF interference into the room.

Wall-mounted emergency stop buttons

The MR examination typically has two wall-mounted emergency stop buttons.

- Magnet quench button.
- Mains electrical power off button.

The location of emergency stop buttons should ensure they are easily accessible to staff while minimizing the risk of accidental activation. A common and effective location is above the height of frequently used equipment, such as patient trolleys, but still within comfortable reach for most staff. To further reduce the risk of unintended activation, it is recommended to install a protective guard flap over any emergency button. The emergency buttons should be clearly labelled as to their purpose.

Real-world example: Shelving in MR Examination room was positioned immediately below the Magnet quench button which did not have a protective cover

An item of equipment was placed on the shelving, partly obscuring the magnet quench button. Subsequently, the item was pushed back on the shelf, inadvertently coming into contact with the emergency button and activating a magnet quench.

Impact: Downtime & cost of replacement helium associated with unintended manual activation of magnet quench

Recovery area

Function

An area for patient recovery that is separate to the preparation area may be considered. This may be helpful to facilitate an efficient workflow if the available size of the preparation area is limited and cannot accommodate multiple patients.

Location

The recovery area may be located outside of the MR Controlled Access Area, although close proximity may be desirable to minimise distance during the transport of any intubated patients if planning to provide MRI scanning under general anaesthetic.

Operational/design considerations

If outside of MRCAA, there may be scope to share the recovery area with other modalities.

For anaesthetic recovery piped oxygen and suction must be available.

Lockable drug cupboards may be required.

MR Control room

Function

The Control room is the hub of the MR suite and is where MR staff will spend significant amounts of time. Activities associated with this room include controlling the scanner, observing the patient whilst in the scanner, performing administrative computer-based tasks associated with the MRI service, taking phone calls and having oversight of activities occurring within other areas of the MR suite.

Location

The MR Control room is located next to the MR Examination room. Ideally, it should either be located close to the entrance to the MR Controlled Access Area (or have other means for MR staff within the MR Control room to observe this entrance, e.g. CCTV) in order to help supervise access to the MR Controlled Access Area, e.g. observing tailgaters.

Operational/design considerations

The Control Room requires sufficient space for the operator console and additional devices such as: a CCTV monitor for patient observation; the patient call/alert system; patient intercom and possible music system; a control system for the power injector; a remote monitor for any patient physiological monitoring equipment; and usually a separate computer for accessing the Hospital Radiology Information System (RIS) and/or the Hospital electronic patient record (EPR) system. More generally, the control room should be of sufficient size (see HBN 06-01) to allow the full range of occupancies expected to be accommodated. Higher occupancies may occur for GA sessions or other specialist scanning activity and should be considered when planning the control room. Guidelines from the Association of Anaesthetists of Great Britain and Ireland (Wilson *et al*. 2019) highlight the need for additional space in the MR Control Room to allow remote anaesthetic monitoring equipment and line-of-sight patient monitoring for all staff, anaesthetists and radiographers.

The MR Control room should provide line of sight overview of the inside of the MR Examination room via a viewing window. A preferred configuration is for the control room to have an uninterrupted view down the magnet bore to allow the MR operator to be able to observe the patient for signs of distress / deterioration. For this reason, viewing from the rear of the magnet is generally undesirable. Where direct line of sight is not feasible, a view down the magnet bore may be provided by additional means such as CCTV.

Additionally, the control room should ideally provide direct line of sight to the area immediately outside of the MR Examination room door, allowing the MR staff within the Control room to observe anyone approaching the MR Examination room.

Shared control rooms for multiple MR systems can be beneficial, e.g. to allow greater flexibility for radiographer support between MR systems, although patient privacy and background noise when communicating with patients should be considered.

Dimmable lighting in the MR Control room is generally helpful to allow MR staff to modify lighting level to be appropriate for viewing MR images.

The use of window blinds/switchable opaque glass for the MR Examination room should be considered to ensure patient privacy for certain MRI examinations. Additionally, their inclusion with other windows in the MR Control room may be appropriate to protect patient confidentiality.

Consideration should be given to what control/alarm panels are to be installed within the MR Control room to immediately alert MR staff to any issues associated with the supporting plant so that they can take appropriate action and potentially minimise any downtime of the MRI service. These should include the following.

- Chiller mimic panel to alert MR staff to any issues with the chiller.
- MR Examination room heating ventilation and air conditioning (HVAC) status. HBN 06-01 recommends that there should be a green indicator light in the control room to confirm to the staff that the ventilation is operational and a red light to indicate that it is not operational or has a fault.
- MR Examination room temp. HBN 06-01 recommends there should be an audible alarm if the ambient room temperature falls outside of the range specified.
- MR Examination room humidity
- Leak detection in MR Technical room
- Oxygen alarm
- Medical gases
- Nurse call for changing rooms/toilet

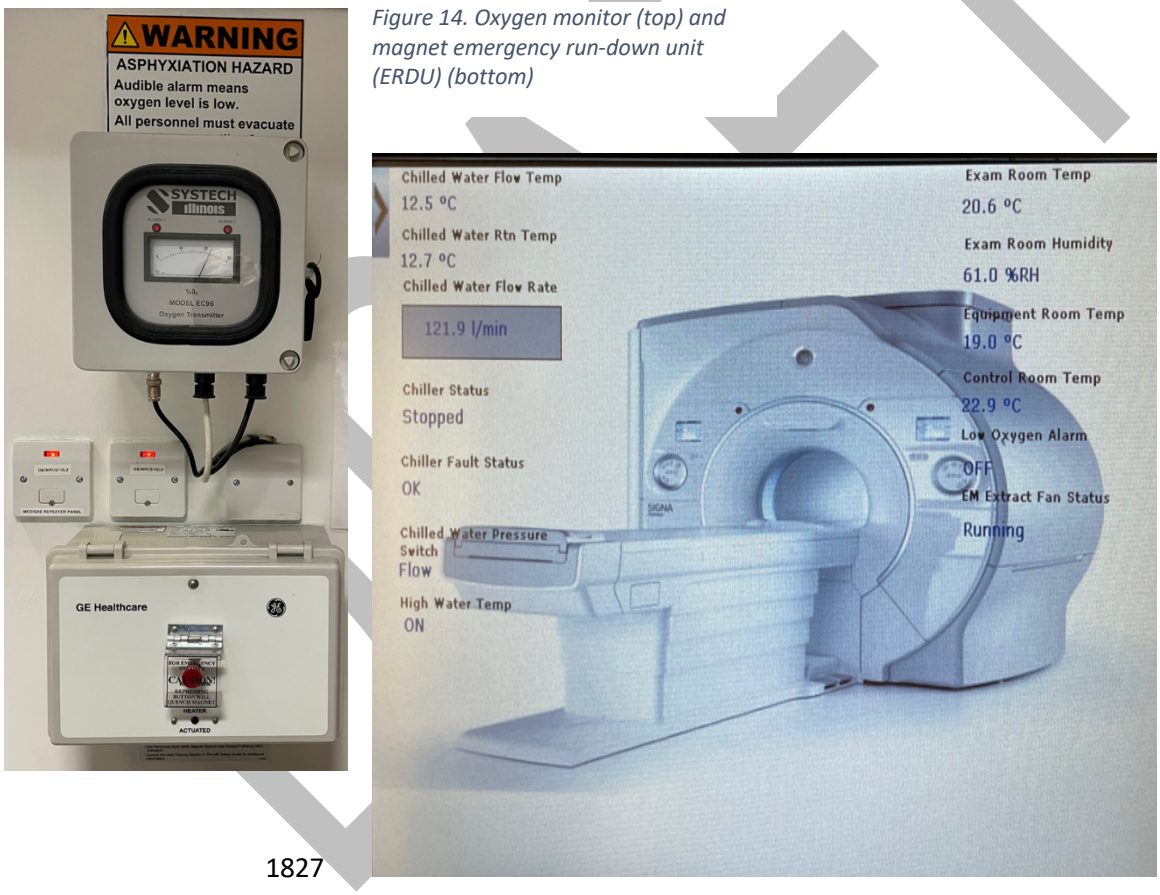


Figure 14. Oxygen monitor (top) and magnet emergency run-down unit (ERDU) (bottom)

Figure 15. Heating, ventilation, and air conditioning (HVAC) mimic panel, providing information on the chilled water entering the facility, magnet and control room temperature and relative humidity. The oxygen sensor alarm and emergency extract fan status are shown as is the chiller status.

The MR Control room should also contain a button to initiate the emergency field shut down unit (more generally known as a quench button) and emergency electrical power off button as well as more standard fittings such as light switches. As with the MR Examination room, these buttons should be positioned to ensure they are easily accessible to staff while minimizing the risk of

accidental activation. A commonly recommended location is above the height of frequently used equipment yet still within comfortable reach for most staff. To further reduce the risk of unintended activation, it is recommended to install a protective guard flap over any emergency buttons. Additionally, both the quench and emergency electrical power-off buttons should be clearly labelled in accordance with MHRA recommendations. Clear labelling of each control/alarm panel should be considered, incorporating a description of what it is, an indication of the normal levels and who should be contacted in the event of an alarm. Figure 16 highlights the following labels from the IPEM MRI safety notices (IPEM 2017).

- MR scanner magnetic field off (magnet quench button)
- MR scanner electrical power off
- MR Examination room emergency air extract
- MR Examination room oxygen monitor
- MR Examination room temperature and humidity.

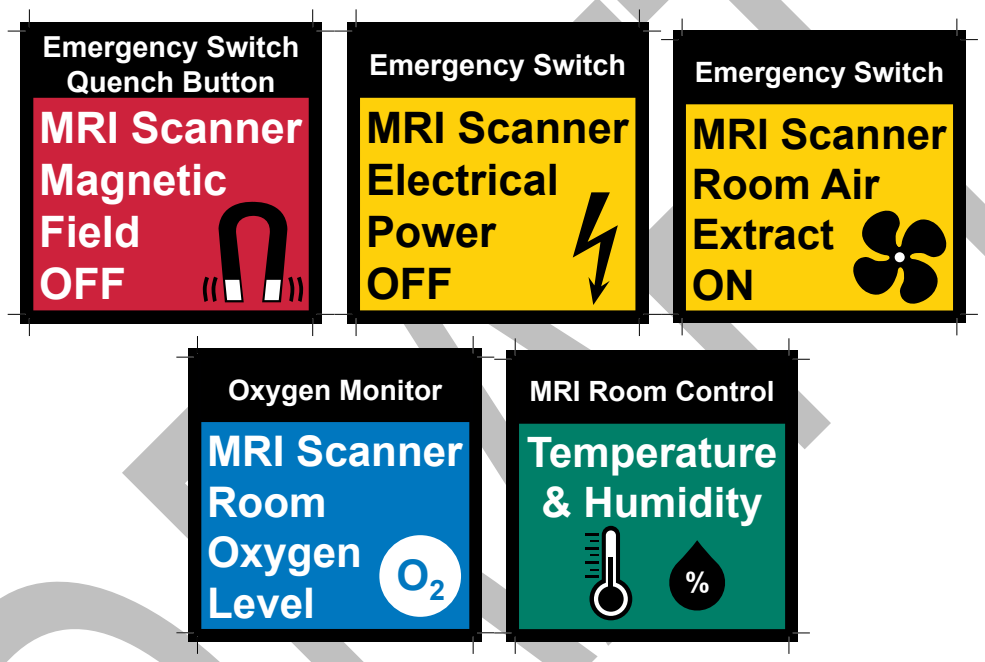


Figure 16. Example of IPEM signage for the labelling of various MR Safety related items.

Real-world example: Chiller mimic panel not installed in MR control room.

On a non-turnkey installation, MR staff missed that a chiller mimic panel was not planned for the MR control room. Consequently, once operational, MR staff were not made aware of chiller problems until they resulted in problems with MR system.

Impact: Chiller alarm panel was retrofitted at additional expense

Given the potentially large number of items of electrical equipment within the control room, it is important to ensure the MR Control room has sufficient number and distribution of power sockets and network ports. It is often helpful to have sockets available both above and below desk height to support a range of connections.

MR Technical room

Function

The MR Technical room accommodates parts of the MR system that are sited outside of the MR Examination room. This equipment is generally housed within multiple equipment cabinets. The technical room may also incorporate additional equipment to support certain MR examinations, e.g. a video projector to support functional MRI studies.

Location

The MR Technical room is generally located adjacent to the MR Examination room as the MR manufacturer will generally specify a maximum length for cables between the MR scanner and the equipment within the MR Technical room. However, this may still allow for a small amount of separation between these two rooms if required. There may be additional reasons for immediate adjacency to the MR Examination room, e.g. for an fMRI projector within the MR Technical room to project into the MR Examination room.

Operational/design considerations

The size of the MR Technical room and the distance between the electronic cabinets and MR system should comply with the MR manufacturer's requirements. Additionally, the MR manufacturer may have requirements for a minimum separation distance between the electronics cabinets of different MR systems at the same nominal field strength (e.g. one MR manufacturer has a recommendation of a 5 m separation), that close proximity of MR Technical rooms or having a shared MR Technical room. When planning adjacent MR Technical rooms, it is recommended to seek advice from potential MRI manufacturers. If adjacent MR systems are planned to be different nominal field strengths (e.g. 1.5T and 3T), then consideration should be given to changes with future scanner replacements.

Entrance to the MR technical room may be from within the MR Controlled Access Area or from outside of the MR Controlled Access Area. Either way, a general door lock is recommended, with the physical key often kept in the MR Control Room. Entrance to the MR Technical Room via the MR Examination room itself should be avoided where possible. Practically, it is desirable for the entrance to the MR Technical room to be relatively close to the MR Control room, particularly for MR engineers who often need to work between these locations when on site.

Generally, the MR Technical room is the location within the MR suite with the greatest requirements in terms of power and chilled water. Additionally, there may be significant requirements for air conditioning. These are all discussed in the section on the supporting plant. Water pipes immediately above the electrical equipment cabinets should be avoided where possible. Consideration should be given to the installation of drip trays above electrical equipment cabinets, ideally with a direct connection to drain. Since the MR technical room is often unoccupied, installation of a leak detection system in any drip trays and in the floor of the MR technical room is advisable with an alarm point within the MR Control room to help ensure swift remedial action in the event of a leak.

Real-world example: Water damage to MRI electrical equipment in the MR Technical Room

Water leak from floor above into MR Technical room leading to damage to electrical equipment.

Impact: £100,000 cost, 3 weeks system down time for replacement of MRI cabinets. A drip tray was subsequently installed above the cabinets with a leak detection system incorporating an alarm in the MR Control room.

Network connections and power sockets within the MR Technical room may be required to support remote monitoring solutions.

Cleaning/storage/staff changing

Consideration should be given to sufficient storage space for cleaning equipment and other items within the MR suite. These may include the following.

- Filters and other consumables for chillers and other supporting plant
- MR Conditional patient transfer equipment
- MR Conditional monitoring equipment
- Radiotherapy planning equipment.

Ideally, MR Safe/MR Conditional items that are to be used within the MR Environment should be stored within the MR Controlled Access Area to help ensure they are not inadvertently swapped with similar equipment that is unsafe to bring into the MR Environment.

Real-world example: MR Safe cleaning equipment stored outside the MR Controlled Access Area inadvertently swapped with ferromagnetic cleaning equipment

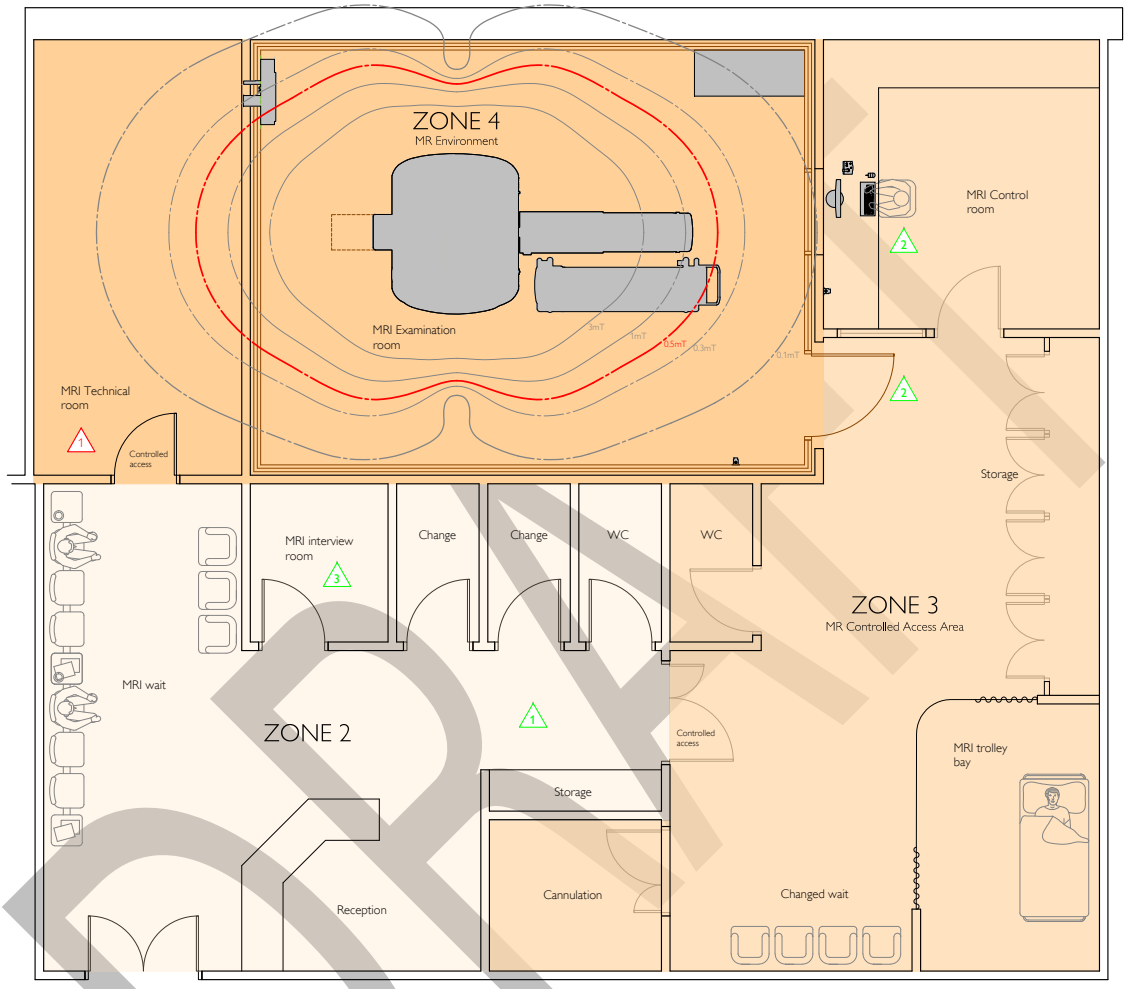
A fully plastic mop, labelled as MR Safe, that was used to clean in the MR Environment was inadvertently swapped with another mop that contained ferromagnetic components. This was subsequently taken into the MR Examination room.

Impact: Ferromagnetic incident where ferromagnetic mop was pulled into the MR scanner bore.

Additionally, space for staff changing including secure storage should be considered.

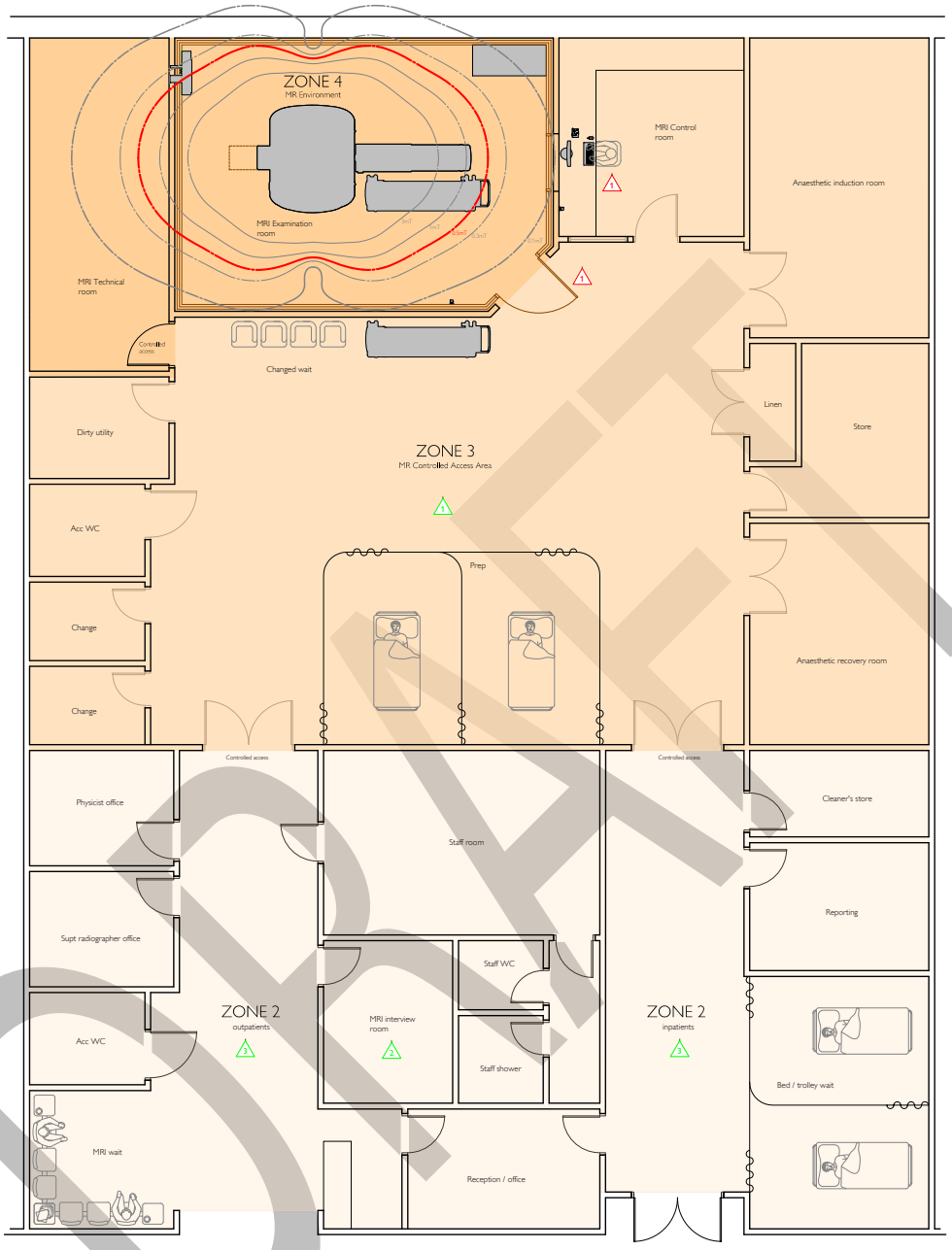
3.5 Examples of an MR suite layout

This section provides examples of different MR suite layouts, highlighting various ideal and non-ideal aspects of each. All of these examples utilise 0.5 mT as the static magnetic field threshold for the B_0 Hazard Area. This threshold was formally increased to 0.9 mT in version 4 of IEC 60601-2-33 (IEC 2022). As discussed in the pre-design phase, a local decision is recommended on where to set the threshold. The ACR zones are highlighted on these example plans in addition to the MR Controlled Access Area and the MR Environment.



Ideal (good practice)	Non-ideal (potential issues)
Clear Zones	Tech room opens outside of MR Controlled Access Area although lockable door.
Good line of sight of RF door	
Interview room outside **MR Controlled Access Area**	
WC within **MR Controlled Access Area**	
View straight down bore from control room	
Prep area of reasonable size	
Changing rooms outside **MR Controlled Access Area**	
Single entrance into **MR Controlled Access Area**	
Spacious MR Examination room	

1944
1945

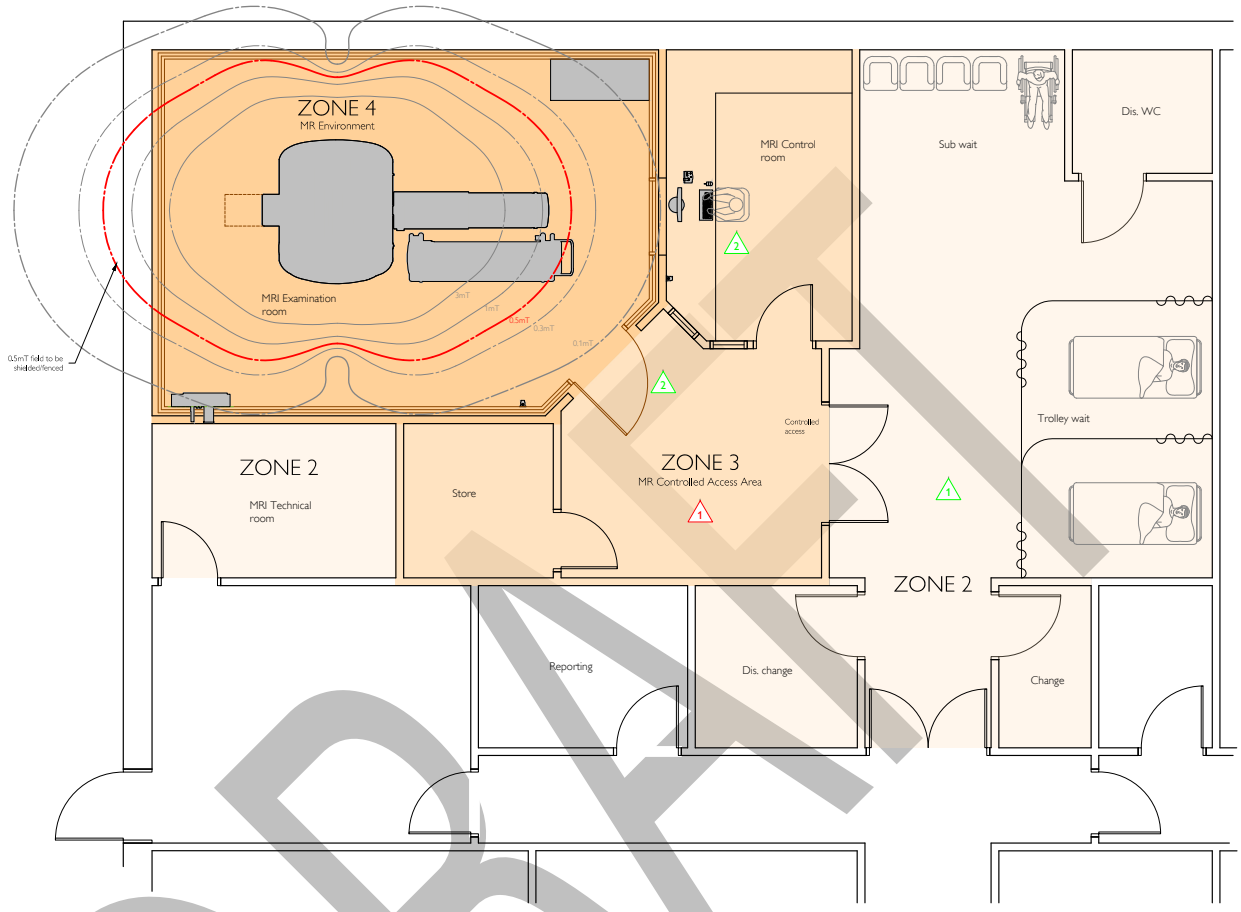


1946
1947

Ideal (good practice)	Non-ideal (potential issues)
Clear Zones	Partial line of sight of RF door
Good line of sight of RF door	Changing rooms inside MR Controlled Access Area
Interview room outside **MR Controlled Access Area**	
WC within **MR Controlled Access Area**	
View straight down bore from control room	
Prep area of reasonable size	
Changing rooms outside **MR Controlled Access Area**	

Single entrance into **MR Controlled Access Area**	
Spacious MR Examination room	

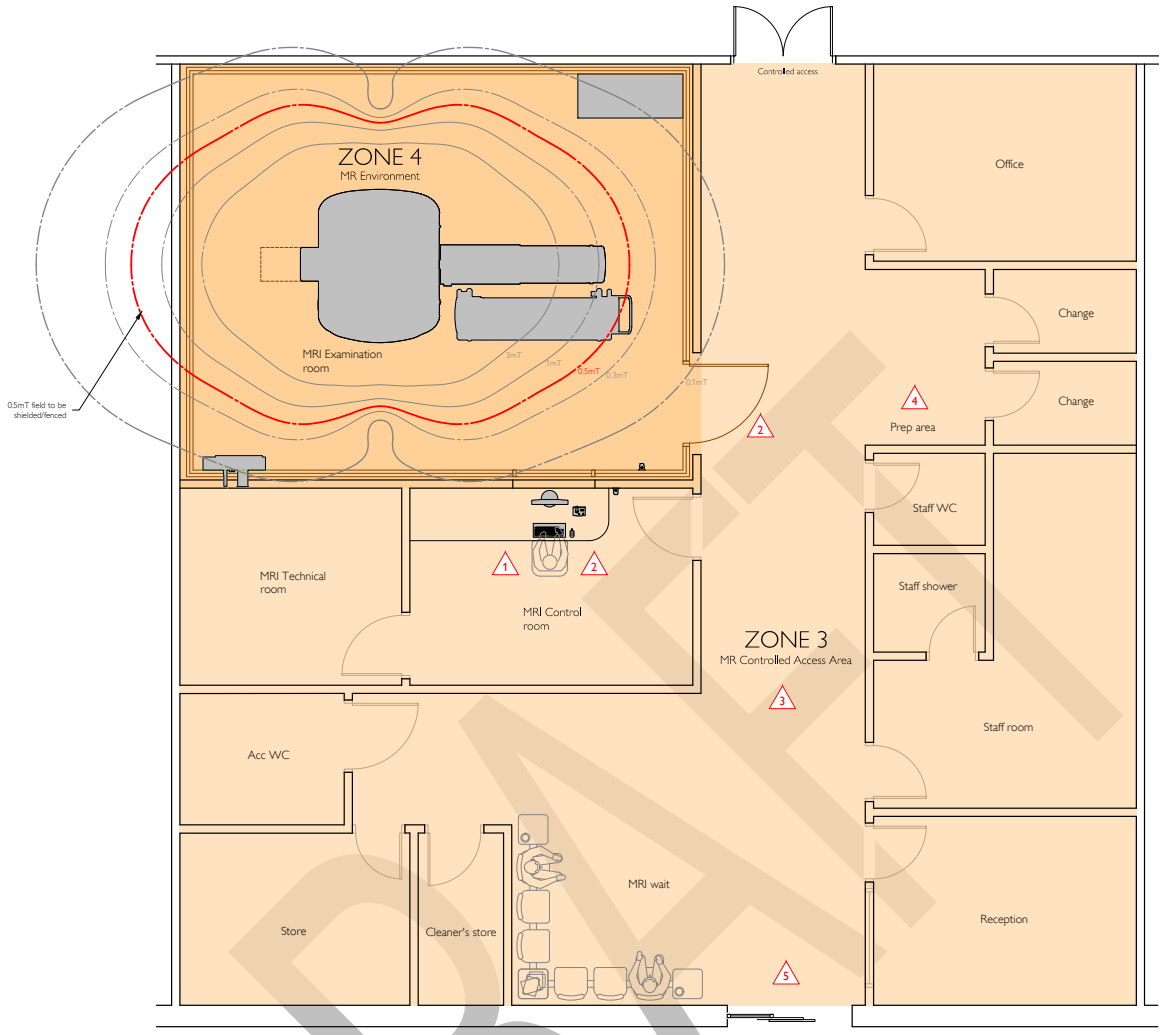
1948
1949



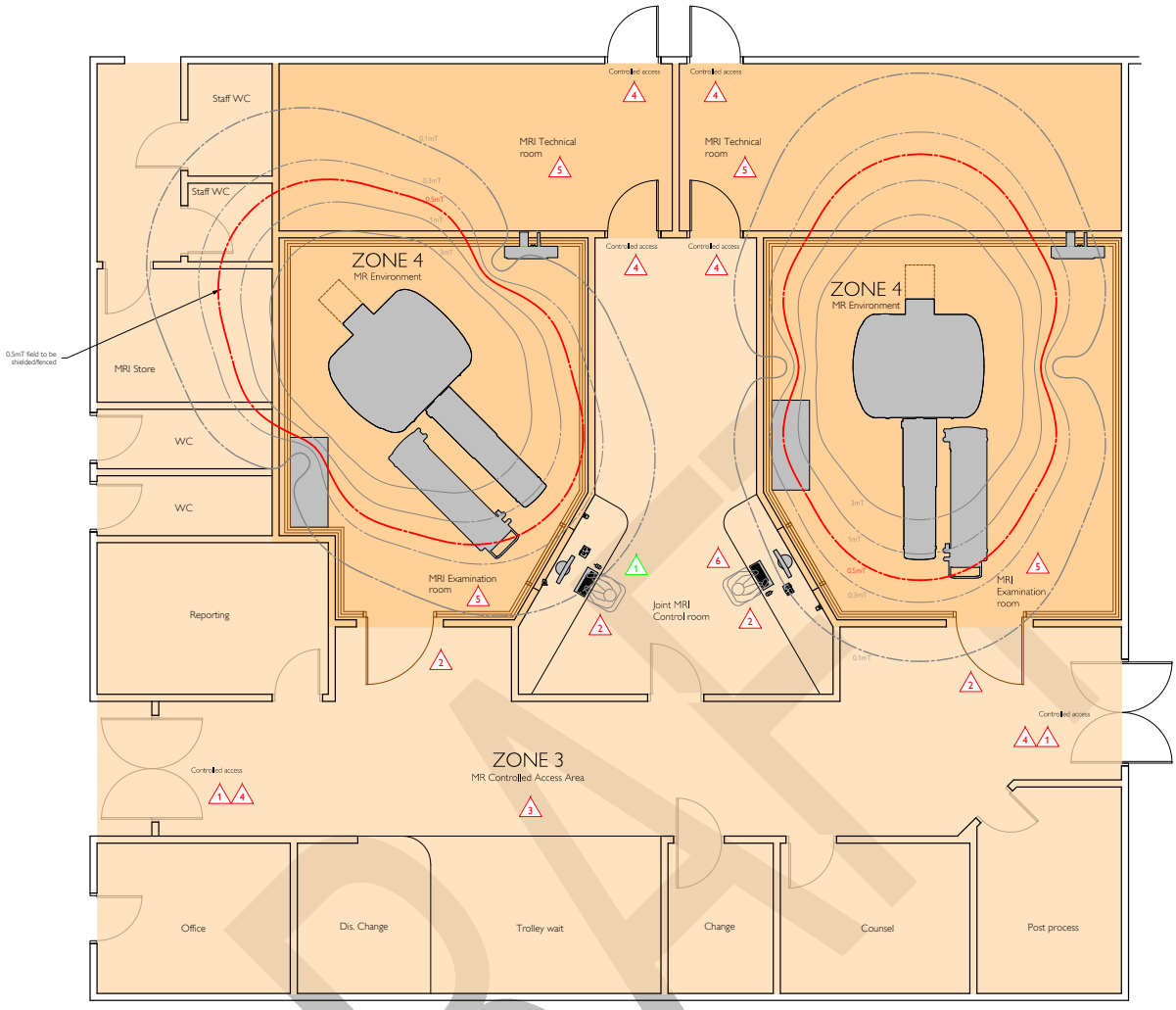
1950

Ideal (good practice)	**Non-ideal (potential issues)**
Clear Zones	Partial line of sight of RF door
Good line of sight of RF door	Changing rooms inside MR Controlled Access Area
Interview room outside **MR Controlled Access Area**	No WC within MR Controlled Access Area
	No clearly identified preparation area.
View straight down bore from control room	B_0 Hazard Area extends out of back wall of magnet requiring either shielding or control of access.
Changing rooms outside **MR Controlled Access Area**	
Single entrance into **MR Controlled Access Area**	

1951
1952



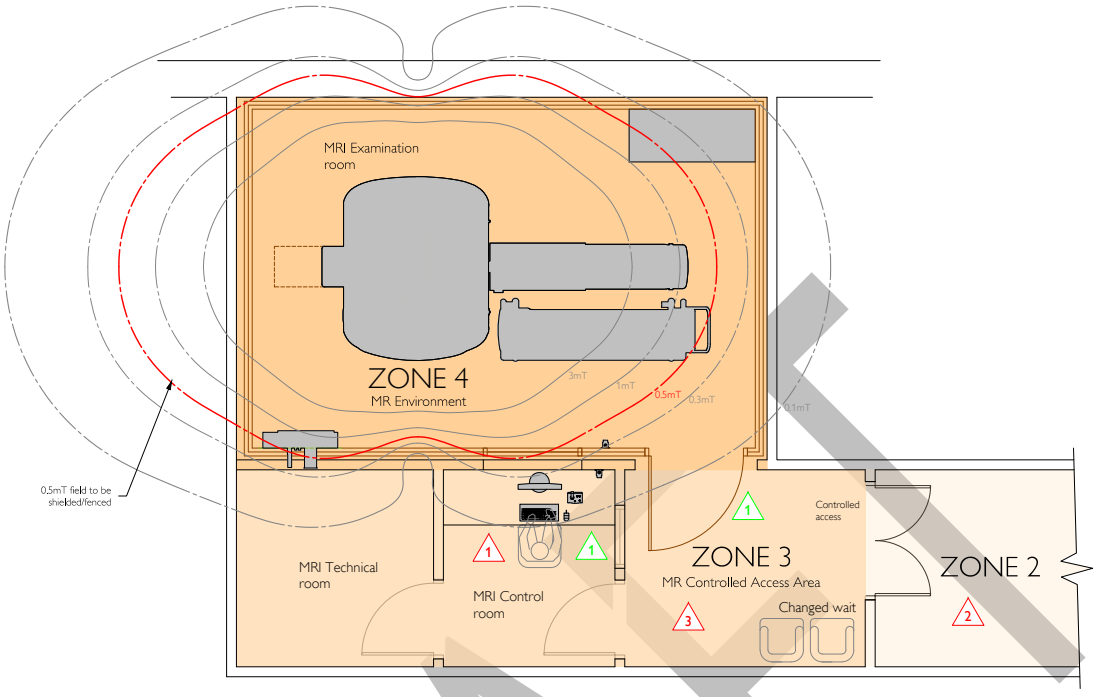
Ideal (good practice)	Non-ideal (potential issues)
Single entrance into **MR Controlled Access Area**	No line of sight of RF door
	Changing rooms inside MR Controlled Access Area
	No WC within MR Controlled Access Area
	Prep area is limited in size and ill defined.
	No interview room
	Side on view of MR scanner from control room.
	Patients have to walk past magnet room to get to reception and waiting areas.
	B_0 Hazard Area extends significantly out of the back wall of magnet requiring either shielding or control of access.



1957

Ideal (good practice)	Non-ideal (potential issues)
View straight down bore from control room (for Left hand scanner)	No line of sight of RF door from control room.
	Changing rooms inside MR Controlled Access Area
	No WC within MR Controlled Access Area
	No prep area
	No interview room
	Five entrances to the MR Controlled Access Area can be difficult to control access as well as providing potential opportunity for MR Controlled Access Area to be used as a walk through route.
	B_0 Hazard Area extends significantly out of the back wall of magnet requiring either shielding or control of access.

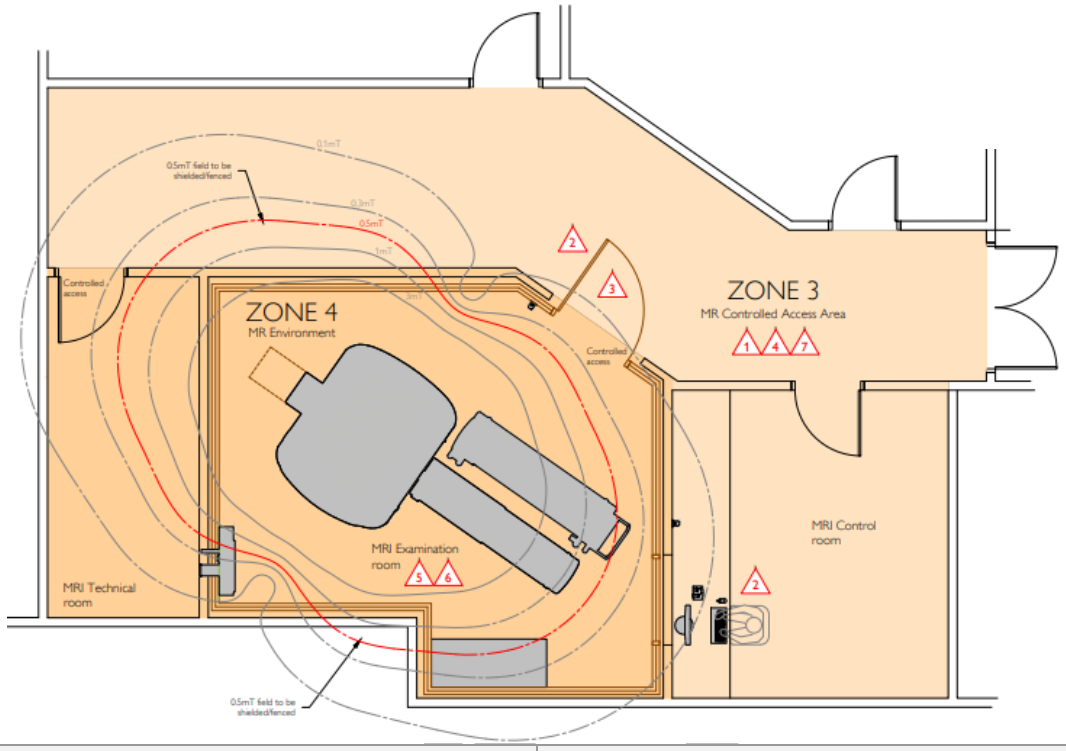
1958
1959
1960



1961

Ideal (good practice)	Non-ideal (potential issues)
Clearly defined zones	No line of sight of RF door from control room.
MR Technical room in **MR Controlled Access Area**	Changing rooms inside MR Controlled Access Area
	No WC within MR Controlled Access Area
	No prep area
	No interview room
	Side view of magnet from control room.
	Magnet room is small
	B_0 Hazard Area extends significantly out of the back wall of magnet requiring either shielding or control of access.

1962
1963



1964

Ideal (good practice)	Non-ideal (potential issues)
Clearly defined zones	Limited line of sight of MR Examination room door from control room.
Tech room in **MR Controlled Access Area**	Changing rooms inside MR Controlled Access Area
Exam room restricted in size and layout.	No WC within MR Controlled Access Area
	No prep area
	No interview room
	Magnet room is small
	B_0 Hazard Area extends significantly out of the back wall of magnet requiring either shielding or control of access.
	Magnet room has complicated shape which may be expensive.
	Exam room opens into busy corridor.

1965
1966

3.6 Supporting plant and items external to the MR suite

Quench pipe

Some of the latest generation of superconducting MR systems require very little helium, such that they can accommodate the helium gas that is produced in the event of a magnet quench within the physical confines of the scanner. However, the majority of clinical MR systems at the time of writing use much larger amounts of helium that require the installation of a quench pipe to vent the helium gas in the event of a magnet quench from the MR scanner to outside of the building. Appropriate design of the quench pipe is important to ensure safety.

Designing the general arrangement of a quench pipe at an early stage of a project, before specialists are engaged, requires careful consideration of several factors. Ultimately, the structural engineer will be responsible for specifying the quench pipe design.

The following steps are recommended for consideration to help guide the design process.

- Understand the Purpose of Quench Pipes. Quench pipes are essential safety features designed to safely carry away helium gas in the event of a magnet quench. They help prevent pressure buildup and potential hazards by providing a controlled path for the escaping gas.
- Locating the MR Examination room. The quench pipe is a consideration when deciding on an appropriate location for the MR Examination room. Due to the size of MRI's, however, the access required for installation or replacement usually dictates that the MR Examination room is located adjacent to an external wall, or in some instances on the top storey below a roof which can be opened for install and replacement. This, in turn, usually means the quench pipe also has near-by access to external air. If the area immediately around the quench pipe outlet is accessible, this should be a restricted area, e.g. governed by a permit to work.
- Coordinate with MRI Equipment Layout. Gain an understanding of the planned layout of the MR suite, including the location and size of the MRI magnet and associated equipment. If the client has not chosen their preferred supplier, the architect may request permission from the client to contact the suppliers that are being considered, in order to request their standard design guidance. This information will influence the placement and routing of quench pipes.
- Check MRI manufacturer requirements. MR manufacturers will typically specify quench pipe requirements for the diameter of the quench pipe related to the total distance and number of turns.
- Identify Potential Quench Pipe Routes. Assess potential routes and locations for quench pipes based on the MR suite's layout and supplier guidance. Consideration should be given to minimizing the length of the quench pipe, and the number of turns required, to reduce resistance. Avoid routing pipes through occupied or sensitive or 'difficult to access' areas of the building. Avoid routing the pipe through fire rated construction to avoid breaching the integrity of the fire line. Plan for appropriate outlet gas discharge locations away from building openings (windows, intake louvres etc) and populated areas. Choose a discharge point at a higher elevation, if feasible and safe, to facilitate better dispersion of gas into the atmosphere. Seek feedback from the client's safety experts, building officials, and other relevant parties to validate the suitability of the proposed discharge location. Particularly for aesthetically-significant buildings, there may be restrictions on the quench pipe exiting through a side wall.
- Some sites may have additional local restrictions. Be prepared to revise the design if additional safety measures or adjustments are recommended. Document the proposed quench pipe general arrangement in preliminary design drawings and specifications. Clearly

communicate the design intent and key risks to future specialists who will further develop and implement the detailed design.

- Identify Potential Quench Pipe Outlet Type. Once the preferred and safest outlet location is identified, choose the type of outlet that best directs the gases away from sensitive areas to allow for safe dispersal of helium gas without causing hazards to nearby individuals or buildings. Avoid locations where gas could be trapped or recirculated back into occupied spaces, for example through mechanical intake louvres. All outlets must be designed to prevent wind-driven precipitation from entering or collecting in the outlet. To mitigate for the potential of birds' nests, the outlet should be covered by a mesh to prohibit birds from entering. Typical outlet types are indicated in Figure 17.

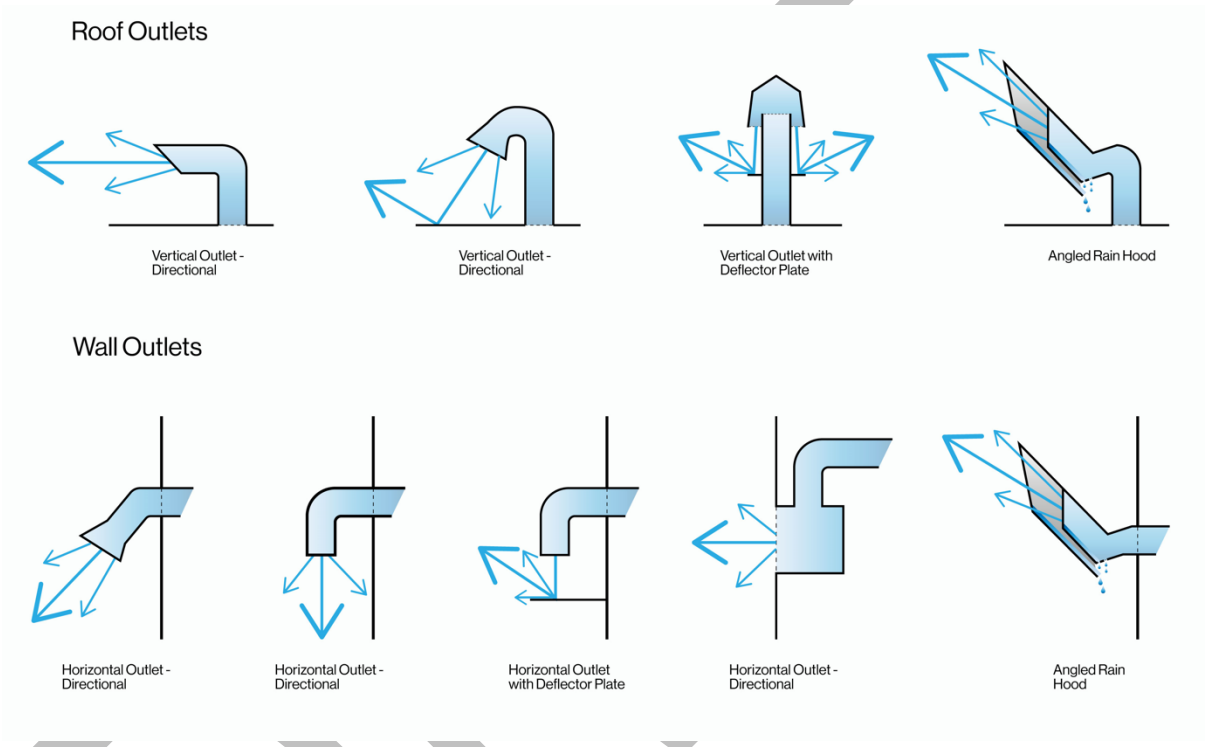


Figure 17. Examples of quench pipe outlet designs.

- Exclusion Zones and Shielding. The recommended exclusion zones around quench pipe outlets can vary greatly between MR manufacturers. Previously, the HBN 06-03 guidance (2003) recommended a minimum of a 3 metre exclusion zone. HBN 06-03 was withdrawn around 2010 for reasons unknown, but the 3 metre minimal exclusion zone is still quoted in MHRA guidelines. The exclusion zone extent is also determined by the detailed design of the outlet. The level of design detail available can vary depending on the MRI supplier. MRI suppliers may provide detailed information for one or more types of outlets, but not necessarily the type that appears most suited to the project circumstances. Additional deflection shielding may also be required to guide the gases to safety and away from sensitive areas. Such additional shielding should normally be designed or specified by the quench pipe designer to ensure a single point of design responsibility.
- Quench Pipe Specialist Design Scope. The design needs to specify that the final outlet type, location and exclusion zone is all to be designed and confirmed by a specialist, commonly a subcontractor to the main contractor. In the even that fully coordinated detail designs are required for building regulations applications, then the client will need to have decided on

the specific MRI equipment to be used and commissioned the full specialised design of the quench pipe and outlet based on the chosen equipment. In any event, it is recommended that the specialist is appointed as early as possible in the design process. The responsibilities of the specialist quench pipe designer should include the following.

  - confirmation or comment on the suitability of the proposed pipe route
  - confirmation or comment on the suitability of the proposed outlet location and type.
  - engagement with the client to agree the outlet type and position with regards to the anticipated maintenance regime.
  - coordination with the MRI equipment supplier to ensure the supplier's technical performance requirements for the quench pipe are clear and understood.
  - advise the architect on the required extent of exclusion zone.
  - engagement with the design team to ensure design responsibilities, especially at points of interface, are clear and confirmed.
  - advising the design team if any additional protection measures are required to the building fabric surrounding the quench pipe. For example, if the quench pipe is directed directly onto a roof.
  - coordination with the design team including structural engineer to finalise all details necessary for construction, including quench pipe fixing points, secondary support structures etc.
  - contribute to the health and safety file and operations and maintenance manual
  - provision of compliance declarations for the quench pipe designs, in accordance with all relevant regulations associated with the specialist's scope of work, for building regulation submission.
  - Consideration of introducing inspection points at regular intervals along the length of the quench pipe within the building to allow the integrity of the quench pipe and any fixings to be visually checked.

- Exclusion Zone Access Control. There should be agreement on a suitable barrier system to prevent accidental access or to deter unauthorised access into the quench danger zone. The barrier system would need to allow access for routine quench pipe inspection and maintenance.
- Consider Engineering Integration. With the project structural engineer, evaluate how quench pipes can be integrated into and fixed to the building's structural design. Whilst project building services engineers are not usually directly involved in the design and specification of the quench pipe, coordination between the pipework and other building services, including at high level within the MR Examination room is important, for example to avoid crossovers and ensuring adequate access.
- Plan for Future Expansion and Maintenance. Anticipate future needs for maintenance and potential upgrades of the MR system. Design quench pipe routes and access points with consideration for ease of maintenance and potential future modifications.
- Consider Future Building Use and Development. Where possible and with advice from the Client, anticipate future changes in building use or nearby developments that could affect the safety of the selected discharge location. Design the quench pipe outlet with flexibility to adapt to evolving circumstances.

Warning signs should be installed near the quench pipe outlet to clearly indicate the risks. Figure 18 shows the example signage for this location from the IPEM MRI safety notices (IPEM 2017).

Figure 18. MRI quench pipe outlet warning signage from IPEM MRI safety notices.

Real-world example: Inappropriate location of Quench Pipe Exhaust

The quench pipe outlet was originally located in area where building work was subsequently required. To enable the building work to be performed safely, the MR scanner was ramped down and the quench pipe outlet was relocated to a more appropriate position.

Impact: around £50K costs to hospital, downtime of MR scanner

Real-world example: Inappropriate location of quench pipe outlet

A quench pipe was installed with the outlet located 3 m from ground height rather than 3 m from head height of person standing underneath.

Impact: Physical barrier retrofitted to create 3 metre exclusion zone around the quench pipe outlet

Real-world example: Inappropriate location of quench pipe outlet

A quench pipe was installed with the outlet located in an area where access was required to service other equipment. This was identified during installation checks, and the quench pipe was relocated to a more suitable location before ramp up of the MR system.

Impact: Minor delay to MR system ramp up

External physical barriers for access restriction.

The installation of physical barriers may be required outside of the MR suite to restrict access to certain areas for the following reasons.

- Hazardous areas such as regions of high magnetic field
- Hazardous areas around the quench pipe outlet.
- Prevent movement of large metal objects, e.g. motor vehicles, immediately adjacent close to the MR suite, that may otherwise negatively impact MRI image quality.

If restriction is only required for the purposes of minimising movement of large metal objects, then more aesthetic options, such as large planter, may provide sufficient obstacles.

Real-world example: Missing bollards to avoid motor vehicles driving/parking adjacent to MR suite.

The design did not take into account the need to restrict moving large metal objects (e.g. vehicles) within a manufacturer-specific distance from the magnet iso-centre to avoid negatively impacting the quality of MR images.

Impact: Physical bollards retrofitted at additional cost

Chilled water supply

Superconducting MR scanners generally require a continuous supply of chilled water to keep the cold head running at all times to minimise helium boil off. Additionally, various electrical equipment in the MR technical room may require substantial cooling during MRI scanning. Typically, the closed-circuit chilled water supply will connect to the MR system in the MR Technical room.

The chilled water supply needs to meet the requirements of the MR manufacturer. However, strong consideration should be given to the provision of duplicate or shared load designs to allow individual chiller faults to be non-critical, particularly if the project brief highlights the importance of minimising downtime of the MRI service. Additionally, consideration should also be given to adequate maintainability of the chilled water system (e.g. appropriate bypass and filtration) to minimise disruption due to maintenance or fault. For some MR systems a backup chiller is listed as essential in the site planning guide. At least one of the main MR manufacturers reports that the majority of new MRI installations now incorporate a backup chiller to minimise the likelihood of MR system downtime. The inclusion of sufficient flow meters and pressure gauges in pipework should be considered to allow troubleshooting of chilled water problems.

It may be helpful to consider further in the design, scope to accommodate the temporary installation of mobile chillers as a further backup option.

Real-world example: Insufficient maintainability of chilled water system

A scanner dedicated chilled water system was installed with a recirculating, filtered water loop. The single filter was equipped with a maintenance bypass valve, allowing periodic filter maintenance without interruption of water flow. Following a water contamination incident, frequent filter cleaning was required. While the filter was bypassed for cleaning, contaminated water entered the scanner, contaminating the scanner's heat exchanger and necessitating downtime for repair.

Impact: In total, 10 episodes of filter blocking causing downtime, and 4 episodes of scanner heat exchanger contamination over an 18 month period.

For coastal locations, chillers utilising corrosion-resistant materials and protective coatings are recommended to ensure durability against corrosion from salt-laden air and higher humidity levels.

Real-world example: Inappropriate chiller installed for coastal location.

Original chiller was identified as inappropriate for an MR suite located close to the coast.

Impact: Chiller replaced at an additional cost of £180,000

Particularly if a decision is made not to go for a backup chiller, the design should consider a solution to keep the cold head running in the event of chiller failure. An option to install a mains water supply/drain into the technical room as a backup cooling solution for when the chiller fails may be possible for some MR systems. Typically, such backup solutions are only sufficient to support the cold head, aiming to avoid excessive helium boil off, and not support of MRI scanning which generally requires much greater levels of cooling. It should be recognised that backup systems have scope to be utilised for extended periods of time and such options should be viewed in conjunction with local sustainability policies.

Air handling

HTM 03-01 recommends any room where anaesthetic gases are planned to be administered for the purposes of general anaesthesia (e.g. induction, MR Examination room, recovery) should have ventilation at 15 air changes/hour. Any other MR Examination rooms (interventional or non-interventional), including those where anaesthetic gases are planned to be administered for the purpose of pain relief or sedation but not full anaesthesia, should be at least 10 air changes/hour. Further details on ventilation are available from HTM 03-01.

The air handling design should comply with any MR manufacturer's requirements. This may include a requirement for the incoming air to the MR Examination room to contain a proportion of non-recirculated air to mitigate for the potential of helium leakage.

The MR Technical room may have a substantial need for air conditioning to avoid overheating of various electrical equipment located within. Additionally, some MR systems, particularly low-helium superconducting systems, may have an air-cooled backup for the cold head in the event of a failure of chilled water supply. These can output a significant amount of heat into the MR Technical room which can be beyond the specification of typical air conditioning units.

MR systems often have particular needs regarding humidity levels within the MR Examination room and Technical Room, with many MR systems requiring a relative humidity around 50% for the MR Examination room. If the humidity is too high then there is a negative impact on patient safety as well as potential damage from condensation. If the humidity is too low, which may be more common during the winter months, then there may be a negative impact on MRI image quality. Importantly, MR manufacturer may refuse to spend time troubleshooting image quality issues if they note the MR Examination room humidity is too low. Hence the common need for both humidification and de-humidification.

The location of humidity control equipment, particularly if it requires servicing, should be agreed with MR staff.

Real-world example: Inappropriate location for humidity control unit.

Rather than the MR Technical room or other appropriate location, the humidity control unit was installed in the MR Control Room where it took up valuable space and was an inconvenience for MR staff each time the unit was serviced. It was subsequently identified there was a lack of communication between the design/installation teams and local MR staff.

Impact: Ongoing inconvenience for MR staff

While many institutions may prefer to manage air temperatures centrally, e.g. via a building management system, some degree of local control may be important to support MRI scanning of certain patients, e.g. neonates. HBN 06-01 recommends that any local adjustment of temperature control should be in line with those referenced in HTM 03-01. An example of the various supporting plant for an MR system is shown below in Figure 19.

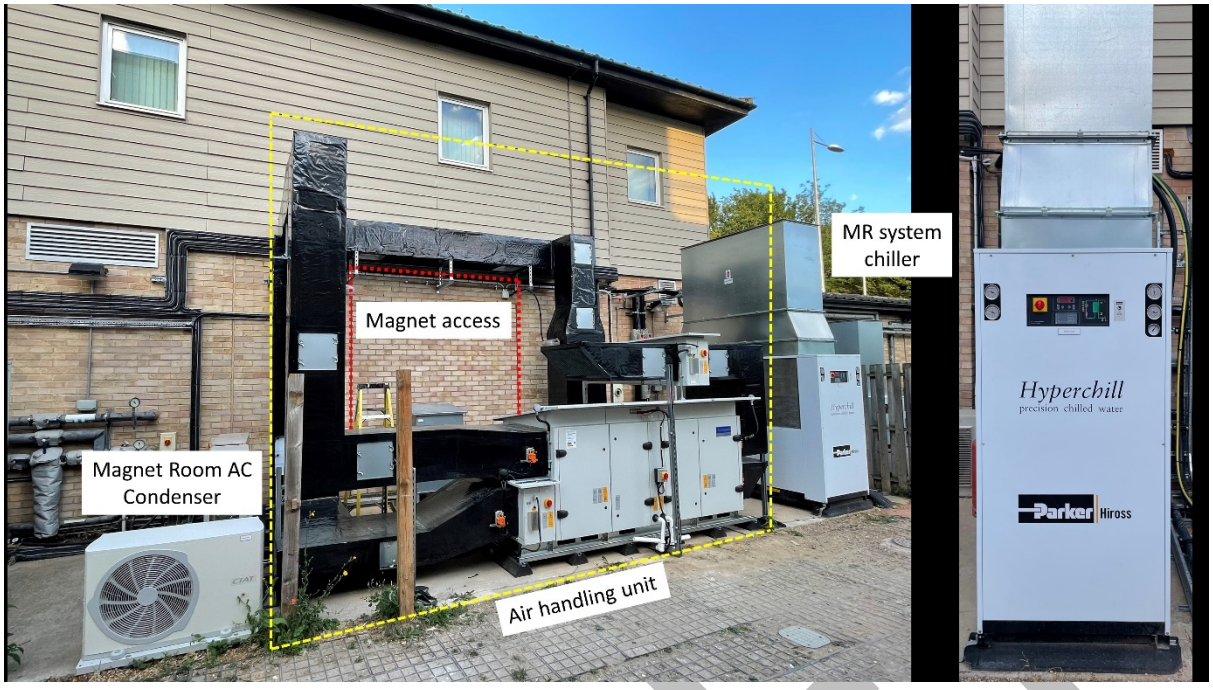


Figure 19. Example of MRI supporting plant. The air handling unit is highlighted by the yellow dotted box. Also shown is the condenser unit for the MR Examination room air conditioning and the MR chiller system that provides chilled water to the MR system heat exchanger located in the equipment room. The red dotted line partially shows the magnet access. This wall is demolished for installation/removal of the magnet.

For MR systems that include a quench pipe, it is recommended that an emergency air extract should be provided from the MR Examination room to mitigate for the possibility of helium leak. At least one MR manufacturer specifies a minimum of 12 room air exchanges per hour for the emergency air extract. The emergency extract duct should be located in the ceiling opposite the entrance to the MR Examination room to draw any potential helium escape away from the room exit. Importantly, emergency air extract systems are typically not sufficient by themselves to fully mitigate for the potential of large amounts of helium gas to be released into the MR Examination room over a short period of time (typically 10s of seconds) in the event of a magnet quench and a failure of the quench pipe. Consequently, as discussed in the section above on the MR Examination room, other forms of room overpressure relief need to be identified and incorporated into the design. The emergency extract ducting should aim for a direct route to an external wall, ideally avoiding crossing into another fire compartment.

The MHRA (MHRA 2021) advise “It is essential that an adequate number of oxygen monitors are installed and that they are regularly maintained.” MR manufacturers may provide an oxygen monitor as part of the MR system. For low helium MR systems that do not require a quench pipe, oxygen monitoring may not be required in accordance with the MR manufacturers guidance. Many oxygen detection systems are based on a chemical sensor that will need replacing multiple times through the lifetime of the MR system. To ensure that oxygen monitors can be maintained, it is important to design the location of the chemical sensor so that it is easily accessible. A common location is attached to the return air duct for the MR Examination room at a location outside of the MR Examination room, e.g. above the MR Control room.

Real-world example: Oxygen sensor installed at a location that was too difficult/hazardous to access

The oxygen sensor for a new MR system was installed at a location that could only be accessed via the outside of the building. This route was deemed too hazardous by maintenance engineers attending to service the oxygen sensor.

Impact: Oxygen sensor was not replaced and eventually failed leaving the MR suite with no oxygen monitoring.

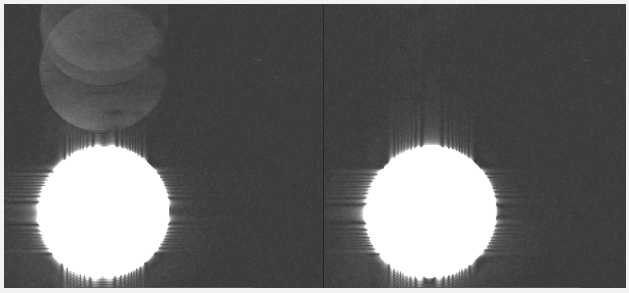
A low oxygen alarm should automatically trigger an emergency air extract fan from the MR Examination room to avoid any delays associated with a manual response. Additional functionality to allow manually initiation of the emergency air extract is advisable to allow pre-emptive operation.

Electrical power supply

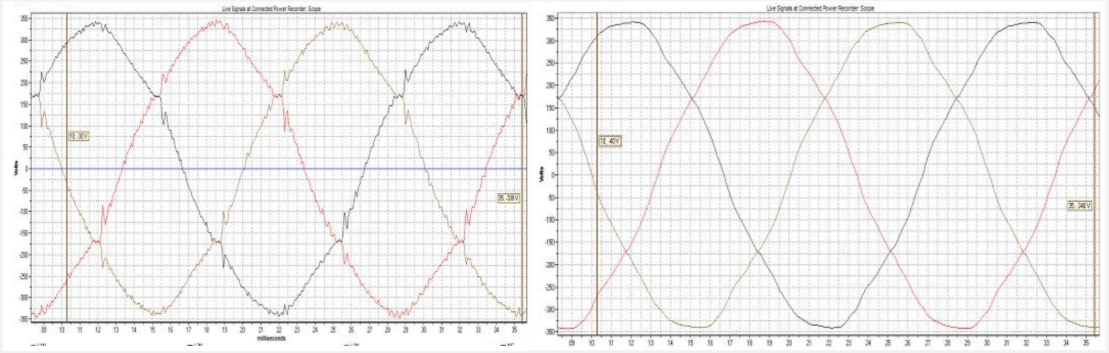
MR systems and supporting plant often have substantial electrical power requirements. For the MR system itself, the MR manufacturer's site planning guide will specify the design capacity of the electrical supply and any other requirements such as permissible voltage variation, phase voltage imbalance, voltage waveform distortion (harmonics) and line impedance. Other electrical equipment attached to the same electrical supply may be a source of power quality problems (HVAC, motors, pumps, generators and lift machinery) such as harmonic distortion. A power quality survey should be considered prior to the design of the electrical supply, to identify any potential problems and design mitigations. An inadequate power supply may result in nuisance tripping of circuit breakers and high levels of harmonic distortion can impact image quality.

Real-world example: Insufficient quality of power supply resulting in intermittent poor image quality

An MR scanner was attached to an electrical switch board that also supplied a large chiller unit. Harmonics on the electricity supply that were generated by the chiller unit caused a noticeable ghosting on the MRI images. This effect was intermittent as it only occurred when the chiller was operating.



The figures below show the quality of the 3-phase electrical supply to the MR system exhibiting the ghosting artefact (left) and for a neighbouring identical MR system that was installed at the same time on a different power supply and did not exhibit the artefact (right). The measured total harmonic distortion for the affected MR scanner (left) was of 4.5%. Although this within the MR manufacturers specification of 5%, it was noticeably greater than the supply for the neighbouring MR scanner (right) that had a measured total harmonic distortion of 3.6%.



Identical Images of a test object with a basic spin echo sequence, acquired with a pump associated with the chiller unit on (left image). The noticeable ghosting was not present with the pump turned off (right image) and remained absent once a harmonic filter was fitted to the pump.

Impact: Cost to fit a harmonic filter to the separate chiller unit.

For replacement MR system projects it is important to check the power requirements, since these may have increased compared to the existing MR system, particularly with higher MRI gradient performance on the many of the current generation of MR systems.

Real-world example: increased power requirements for replacement MR scanner not planned for.

This was not noticed until MR acceptance testing when the power consistently tripped when performing MRI sequences with high intensity gradient switching.

Impact: Delays to clinical use while increased power supply was retrofitted.

Power requirements for all other electrical equipment that is intended to be used within the MR suite should also be considered. The power supply to any equipment that is intended to be used within the MR Examination room, e.g. power injector, anaesthetic machine, patient monitoring, will be required to go through a filter into the RF cage.

Consideration should be made to secondary power supply (SPS) support, e.g. generator, for MR systems and other critical electrical equipment within the MR suite in the event of a failure of the primary electrical supply. HTM 06-01 includes MR scanners in a list of examples that may be regarded as risk grade B with regards loss of power supply, the highest risk level below life support or complex surgery. If a decision is made against SPS support for MR scanning, further consideration should be made to SPS support to chillers and cryocrompressor to avoid problems with helium boil of. This will involve the provision of emergency power supply for the compressor and the supporting chiller. Prolonged periods (days) without a cryocompressor will result in a need for replacement helium, typically at additional cost to the institution. For low helium MR systems, shorter power interruptions may result in a magnet quench which may require a few days to recover from and potentially require magnet reshimming. In cases where availability of MRI is necessary even during a mains supply failure, then the design and quality of the essential supply should be validated to ensure that the MRI equipment will operate as intended.

Tertiary power supplies such as an uninterruptable power supply (UPS) may be considered to provide short-term power to the MR system (or components of the system) and supporting plant in the event of a failure of the primary electrical supply to cover the delay before the SPS becomes available and/or allow systems to be shut down normally. HTM 06-01 provides general guidance for this and power issues more generally. Provision of a UPS to maintain operation of the entire MR system may be more relevant in special cases, such as interventional or intraoperative use, and specifications for an appropriate UPS may be found in MR manufacturers' site planning guides. More generally, UPS backup for the whole MR system is likely to be cost prohibitive in many situations, but consideration should be given to designing in UPS support for the following components of the MR system.

- Remote monitoring systems – to ensure the MR system is continuously monitored, allowing faults to be identified and addressed promptly.
- MR console computer – to avoid data corruption.
- Power sockets within the MR Examination room, e.g. for patient monitoring.

Real-world example: Corruption of non-UPS supported MRI host computer following mains power failure.

As a result of an unexpected mains power failure, the MRI host computer became corrupted and required a complete rebuild to resolve.

Impact: At least 2 days downtime associated with rebuilding of MR host computer. Loss of all changes to protocols and other settings made since the last backup was performed.

Building management systems

Integration of supporting plant into a Building Management System (BMS) can be valuable for identifying faults early, particularly when the scanner is not in use. Where environmental conditions are monitored or adjusted remotely, consideration should be given to providing additional local controls—for example, allowing limited-range temperature adjustments within the MR Examination room.

Clear escalation procedures should be in place to ensure that the local MRI service understands the extent of BMS integration and the associated response processes (e.g., communication routes, monitoring periods such as 24-hour observation, and required response times). Additional local protocols should also be established to guide staff when faults are detected before any BMS alarm-driven actions are initiated. Departments responsible for managing the BMS should understand the required actions and response times for each fault type linked into the system.

Potential use of the MR suite outside core hours, e.g. extended hours and on-call cases, should be considered as part of a BMS-managed air handling unit to avoid incidents where operation is reduced/disabled when required.

IT options & configuration

To allow setup of IT workflows, sites will be required to pass on details of basic IT options (RIS worklist, PACS) to the MR manufacturer so that they can be configured during installation. As part of this, sites are encouraged to consider potential options for IT options on the MR system more broadly which may help to support better workflows. Options may include the following.

- Worklists. Some MR systems provide functionality for multiple worklists.
- DICOM nodes. Connections to other DICOM nodes in addition to PACS. For each DICOM node, various options may be available, including the following.
    - Query/retrieve
    - Automatic send/archive of DICOMs. Some MR systems offer functionality to auto-send selected data based on specific DICOM tags.
    - DICOM Storage Commitment – provides confirmation message back to the MR system that DICOMs have been received successfully.
- MPPS (Modality Performed Procedure Step).
- DICOM Study Description. Some MR systems offer an option to set this to match the Requested procedure from the worklist instead of the user-selected exam protocol.
- Enhanced DICOM. This offers many advantages over what is often referred to as standard or classic DICOM, including faster data transfer and capture of additional information in the DICOM metadata. However, although Enhanced DICOM was introduced in the mid-2000 there are some IT systems that may not support this. Sites should consider not only their PACS, but other 3rd party systems in use within the local organisation. Workaround options

to produce standard DICOM versions of datasets when required should be considered. This may be relevant when considering the need for transfer of DICOMs between institutions.

- NTP (network time protocol) server. Linking the MR system to an available NTP server helps to ensure an accurate time on the MRI host computer and subsequently an accurate time stamp on DICOM images which may be important for certain applications. Even if accurate at installation, without a link to an NTP server, the MR system clock may drift significantly over the lifetime of the MR scanner.
- Remote monitoring options. The MR manufacturer should be able to provide requirements for network connections and institutional firewalls to allow them to remotely connect and monitor the MR system. Some remote monitoring options may place additional requirements on the design, e.g. power socket and a network connection in the MR Technical room.
- Additional options for connected DVDs, USB drives, network shares and printers.

MR manufacturers provide DICOM conformance statements which may help to understand some of the options available.

A network connection between the MR system and any associated workstations to the MR manufacturer is used for remote monitoring, technical and applications support. The MR manufacturer should provide details regarding local firewall configurations that are required to enable remote connection. Project managers should plan for change requests to be submitted to local IT teams in a timely manner to help ensure approvals can be obtained to ensure changes are implemented when required. For conventional superconducting MR systems, it is particularly important for this to be in place by the time of delivery, as remote monitoring is a key mitigation for certain issues that can result in significant additional cost and delays if not addressed in a timely manner.

Real-world example: delays in firewall configuration to enable remote monitoring

Network firewall changes required to enable the MRI manufacturer to remotely connect to the MR scanner to monitor its status were not in place when the magnet quenched shortly after installation. The magnet quench happened on Friday evening was not discovered until staff returned on the following week. During this time ice had formed in the magnet cryostat. This required extensive work to remove and cool the magnet down.

Impact: Approx £150K additional cost to project. Approx 2 weeks delay to project

3.7 Summary & checklist

Design team	✓
Design team includes representation from all professional groups to covers the technical aspects of the design?	
Design team includes representation from all the different clinical groups that are intended to use the space?	
Clinical staff within design team allocated sufficient time to allow them to fully engage and contribute to the design team?	
Design team confirmed the final design meets the project brief?	

MR suite layout and general design	✓
General design options to make the space more patient-friendly considered?	
The MR Controlled Access Area is appropriately defined?	
Doors to MR Controlled Access Area are self-closing and self-locking?	
The MR Environment is appropriately defined?	
Appropriate signage for MR Controlled Access Area and MR Environment?	
Appropriate definition of fire zones?	
How a general fire alarm in the hospital will impact on access control for the MR Controlled Access Area considered?	
Considered use of non-ferromagnetic fire extinguishers throughout the MR Controlled Access Area or whole MR suite?	
Delivery and extraction route of MR scanner(s) identified?	

Reception and waiting area	✓
Sufficient seating?	

Pre-change preparation area	✓
Additional space for MRI simulator preparation?	

Patient screening areas / interview room	✓
Appropriate auditory and visual privacy?	
Support for current/future electronic patient screening requirements?	

Patient transfer area	✓
Defined location inside/outside of MR Controlled Access Area after operational and MR Safety considerations?	
Location for safe storage of trolleys and wheelchairs that are unsafe for MRI, preferably outside the MR Controlled Access Area?	
Consideration of patient hoist?	

Patient changing rooms	✓
Sufficient number of rooms to accommodate planned patient throughput, including consideration of potential future patient throughput?	

Lockers for patients to securely store clothing and personal items?	
Consideration of non-ferromagnetic locker keys?	
Storage space for both clean and used MR Safe clothing?	
Space for patients in wheelchairs?	
Nurse call?	
Ability to gain access to room in an emergency?	

2375
2376

Sub-waiting area	✓
Appropriate access to patient toilets?	
Space for patients in wheelchairs?	
Consideration of ferromagnetic detection system to support screening prior to entry to the MR Controlled Access Area?	

2377
2378

Patient preparation area	✓
Sufficient number of cannulation chairs?	
Sufficient space to allow easy manoeuvring of an MR Conditional trolley or dockable MR table in/out of the MR Examination room?	
Patient preparation area directly visible from MR Control room?	
Sufficient space for sedation/anaesthetic induction and recovery?	
Provision of medical gases considered?	
Sufficient space for general patient recovery if no separate recovery area?	
Sufficient space for patient transfer if there is no dedicated space for this outside of the MR Controlled Access Area?	
Sufficient space for in-patient MR Safety screening if there is no dedicated interview area for this patient cohort?	
Sufficient space for 'holding area' whilst an in-patient is waiting to return to the ward?	
Additional WC within the MR Controlled Access Area considered?	

2379
2380

MR Examination room	✓
MR manufacturers requirements for space are met?	
Proposed position of MR scanner meets MR manufacturer's specifications for proximity to items that may impact performance of MR imaging?	
Proposed position of MR scanner to nearby equipment that may be adversely impacted by the fringe magnetic field considered?	
Sufficient space for easy and safe transfer of all patients in/out of the MR Examination room and on/off the MR scanner table including in an emergency patient evacuation?	
Sufficient space for required scanner table movement?	
Sufficient space to accommodate all equipment to support all planned MR procedures, e.g. power injectors anaesthetic machines, monitoring, po, biopsy, radiotherapy planning lasers	
Position of MR scanner and location of window into MR Control room provide a clear view down the scanner bore from the MR Control room?	
Provision of medical gases?	
Consideration of anti-vibration pads?	
Consideration of all relevant frequencies for RF cage testing if multi-nuclear MR system?	
Concrete slab is appropriate depth to accommodate RF cage to avoid step into the MR Examination room?	
Concrete slab is sufficiently flat for the RF cage?	

Concrete slab is sufficiently cured to accommodate the RF cage?	
Building is sufficiently weather-tight to support building of RF cage?	
Location and size of all waveguides confirmed with the intended users?	
Consideration of waveguide solutions within MR examination room door allowing placement of non-conducting lines without disconnecting from patient?	
Consideration of additional penetration panel for future use?	
Consideration of additional penetration panels in RF cage for connections into the MR Examination room that are not the responsibility of the MRI manufacturer?	
MR manufacturer's specifications met for minimum distance between the MR system penetration panel and other penetration panels?	
Sufficient clearance around penetration panels to allow access for future modifications?	
Appropriate signage on and around MR Examination room door?	
Consideration of retractable belt barrier outside MR Examination room?	
For MR system with quench pipes, consideration of mitigations for room over-pressure?	
Consideration of mitigation options for MR Examination room door failure?	
Consideration of the potential need for magnetic shielding from default plans of MRI fringe field (not taking local structure into account)?	
If required, calculations performed taking local structural environment into account for the MRI fringe fields and any required magnetic shielding to reduce extent of B_0 Hazard Area into areas adjacent to the MR Examination room?	
Confirmation structure can support the required magnetic shielding?	
Confirmation location of magnetic shielding is compliant with MR manufacturer's specifications?	
Consideration of acoustic noise transmission to areas outside of the MR suite?	
Consideration of acoustic noise protection within the MR suite?	
Sufficient patient privacy during MRI examination?	
LED lighting suitable for MR Examination rooms?	
LED lighting of sufficient with sufficient lux levels?	
Consideration of dimmable/coloured lighting?	
Light switch located outside the MR Examination room?	
Consideration of emergency lighting?	
Consideration of artificial skylights and illuminated wall panels?	
Consideration of patient video system?	
Suitable floor demarcation?	
Consideration of fitted hooks/anchor points in the walls	
Adequate storage for MRI equipment and consumables including consideration of manual handling issues?	
Consideration of mains power sockets in the room?	
Consideration of network ports in the room?	
Appropriate location of emergency stop buttons?	
Protective guard for emergency stop buttons?	
Appropriate signage for emergency stop buttons?	

Recovery area	✓
If anaesthetic recovery planned, piped oxygen and suction planned?	

MR Control room	✓
Sufficient size to allow accommodation of the full range of expected occupancies (including anaesthetics where planned)?	
Direct line of sight down the magnet bore?	
Direct line of sight to the area immediately outside of the MR Examination room door?	
Consideration of patient privacy and background noise if shared MR Control rooms are planned?	
Dimmable room lighting?	
Consideration of window blinds/switchable opaque glass for patient confidentiality?	
Consideration of control/alarm panels?	
All control/alarm panels appropriately labelled?	
Appropriate location of emergency stop buttons?	
Emergency stop buttons appropriately labelled?	
Sufficient number and position of power sockets and network ports?	

MR Technical room	✓
Complies with MR manufacturer's minimum space requirements?	
Position of electronic cabinets comply with MR manufacturer's requirements for distance to MR scanner?	
Distance between electronic cabinets supporting MR scanners at the same nominal field strength comply with any MR manufacturer's requirements for separation distance?	
Consideration of drip tray installation above electronic cabinets & associated leak detection alarm?	
Sufficient mains plugs and network ports?	

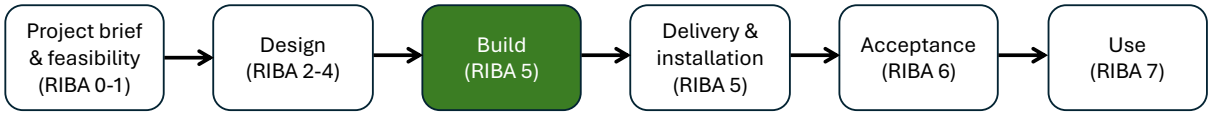
Cleaning/storage/staff changing	✓
Sufficient storage space for cleaning equipment and other items?	
Sufficient space for staff changing?	

Supporting plant	✓
Quench pipe design complies with requirements of the MR manufacturer?	
Appropriate exclusion zone including consideration of physical barriers around quench pipe outlet?	
Appropriate warning signage around quench pipe outlet?	
Consideration of physical barriers to increase distance of moving motor vehicles near MR suite?	
Chilled water supply meets the MR manufacturer's requirements?	
Consideration of duplicate/shared load chiller designs?	
Sufficient flow meters and pressure gauges to support troubleshooting?	

Consideration to design in scope for integrating mobile chillers as backup solution?	
Appropriate chiller options if coastal location?	
Consideration of mains water backup to maintain cold head operation?	
Air handling design complies with HTM 03-01?	
Air handing meets MR manufacturer's requirements?	
Humidity control design to meet MR manufacturer's requirements?	
Location of humidity control equipment appropriate for MR staff?	
Consideration of local control for MR Examination room temperature?	
For MR systems with quench pipe, appropriate emergency extract system, including position of extract duct in MR Examination room?	
For MR systems with quench pipe, oxygen monitor planned with an automatic trigger of emergency air extract?	
Appropriate location of oxygen sensor to support ease of access for servicing?	
Electrical power supply meets MR manufacturer's requirements?	
Consideration of secondary power supply support?	
Consideration of battery (UPS) backup for key items of equipment?	
Clarity with MR staff regarding BMS operation and fault reporting?	
Potential use of MR suite outside core hour considered for BMS-managed air handling unit?	
Consideration of MR system IT options?	
Timely submission of MR manufacturer's IT requirements to local IT teams planned?	

2391

4 Build (RIBA stage 5)



4.1 Introduction

This section covers the building works associated with a new MRI installation, prior to the delivery and installation of the MR system. The involvement of multiple contractors at this stage of the project requires careful coordination and effective communication to ensure details of the design are fully realised as intended and that unexpected issues are managed appropriately. This may be particularly important for non-turnkey installations if one or more contractors have no or limited previous experience of working on new MRI installations with the additional issues that they need to consider.

Project plans should include sufficient time during the build stage to allow for equipment installation and commissioning before key timepoints, in particular the delivery of the magnet and subsequently the magnet ramp-up. These two timepoints form two of the subsections below, together with a further subsections on issues associated with the removal of a previous MR system, a new RF cage and the magnet quench pipe.

If some aspects of the build are required to overlap with the installation of the MR system, then this should be planned with the MR manufacturer in advance, especially if there is a need to ramp the magnet down for certain items to be completed. If looking to do any such work with magnet at field, then there will be a need to implement appropriate screening of individuals and equipment. Additionally, it is important to incorporate reasonable contingency within the plan to help ensure unexpected problems can be accommodated in a timely manner, ideally avoiding the need to delay subsequent steps in the project that in turn can result in much more substantial delays to overall project completion.

It is important for the project team to meet regularly during the build phase, although frequency may vary, e.g. monthly for pre-commencement, then weekly for the final stages. These meetings are opportunities to discuss general progress, any issues arising such as unexpected delays and necessary re-scheduling, and to make any final decisions on design. It is helpful to provide the project team with an up-to-date schedule of installation and commissioning (e.g. as a Gantt chart or spreadsheet) so that any delays and scheduled activities are shared and planned for in terms of availability of other staff groups/contractors, applications training and ultimately planning for the the first clinical lists following handover. Examples of items that might appear in such a schedule are listed below in Table 3.

Activity	typical duration [days]	Comments
Consider: Helium fill and QA if redundant system being sold	2	
Decommissioning and ramp down of current MR system (if appropriate)	1-2	For replacement of a current MR system
Erection of structural scaffolding access and landing platform	1-3	For systems *not* being installed on ground floor

Form MRI entry/exit panel	1-2	
Remove MRI & existing chiller	1-3	
Strip existing RF cage structure & associated mechanical & electrical works throughout	10-20	
Check and form floor levels & service openings to walls		
Take down existing walls and install new		
1st mechanical and electrical installation	3-8	
Install RF Cabin and carry out RF cage test	5-8	
Form filter cupboard in cage	1-2	
Plasterboard & plastering throughout	3-5	
Doors & joinery fitted furniture	2-5	
Electrical Mains GO LIVE Date by Trust	Milestone date	
Suspended ceiling grids	1-2	
2nd mechanical and electrical installation	2-5	
Install LED Lighting	1-2	
Mechanical, electrical commissioning	1-5	
Decoration throughout	2-5	
Floor coverings throughout	2-4	Install permanent floor markings of magnetic field isocontours in MR Examination room if required
Medical gases, scanner ventilation works	1-5	Preferably prior scanner delivery
Delivery checks	1 day	Prior MRI release for shipment
Snagging & post snagging mechanical &electrical /building works	1-3	

Table 3. Example activities associated with the build phase of a new MRI installation project.

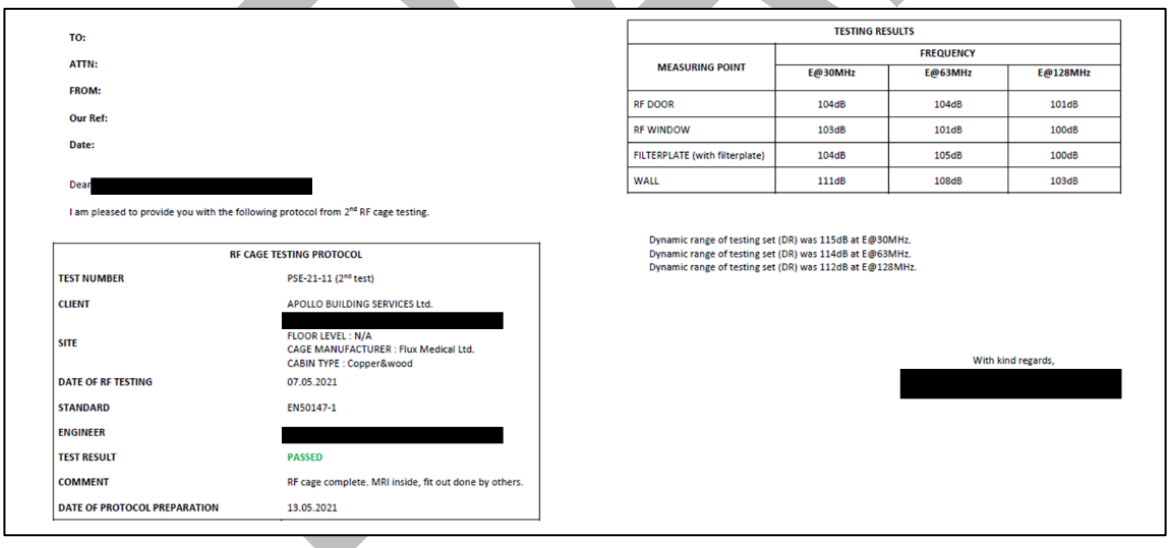
4.2 Removal of old MR system

For replacement MR scanner projects that include a new RF cage, there will be a need to remove the old MR scanner near the start of the building works before arrival of the new MR scanner. Projects where the existing RF cage is being retained may provide scope for the removal of the old scanner and delivery of the new MR scanner to occur around the same time, e.g. over a single weekend, utilising the same exit/delivery route including scaffolding, creation of MRI entry/exit panels, propping and ramps as well as a single crane event. However, this may limit the scope to deal with unexpected issues.

Typically, decommissioning, ramp down and removal of an existing MR scanner will be organised by the MRI manufacturer of the new MR system, although this may be subcontracted to specialists dealing in used MRI equipment.

4.3 RF cage

When the main building structure is ready, construction of the RF cage is one of the first items in the build phase. Typically, the MR manufacturers specifications for the RF cage are confirmed by the RF cage manufacturer immediately after the cage has been built and then again immediately after the RF cage is resealed following delivery of the MR scanner. These measurements are performed with the RF cage disconnected from the earth reference point, allowing an electrical resistance measurement to be taken to demonstrate the absence of any additional earthing. It may be helpful for a member of the physics team that will be performing the acceptance testing to witness these measurements on behalf of the MR Responsible Organisation. An RF cage certificate documenting the results should be provided demonstrating that the system complies with the manufacturers required shielding effectiveness. An example of this is shown in Figure 20.



TO:

ATTN:

FROM:

Our Ref:

Date:

Dear [redacted]

I am pleased to provide you with the following protocol from 2nd RF cage testing.

RF CAGE TESTING PROTOCOL	
TEST NUMBER	PSE-21-11 (2nd test)
CLIENT	APOLLO BUILDING SERVICES Ltd.
SITE	[redacted] FLOOR LEVEL : N/A CAGE MANUFACTURER : Flux Medical Ltd. CABIN TYPE : Copper&wood
DATE OF RF TESTING	07.05.2021
STANDARD	EN50147-1
ENGINEER	[redacted]
TEST RESULT	PASSED
COMMENT	RF cage complete. MRI inside, fit out done by others.
DATE OF PROTOCOL PREPARATION	13.05.2021

TESTING RESULTS			
MEASURING POINT	FREQUENCY		
	E@30MHz	E@63MHz	E@128MHz
RF DOOR	104dB	104dB	101dB
RF WINDOW	103dB	101dB	100dB
FILTERPLATE (with filterplate)	104dB	105dB	100dB
WALL	111dB	108dB	103dB

Dynamic range of testing set (DR) was 115dB at E@30MHz.
Dynamic range of testing set (DR) was 114dB at E@63MHz.
Dynamic range of testing set (DR) was 112dB at E@128MHz.

With kind regards,

[redacted]

Figure 20. Example RF cabin results, showing the shielding effectiveness at 30 MHz, 63 MHz and 128 MHz, demonstrating all results were greater than 100 dB.

At this point, it is recommended to confirm that all planned waveguides and filter panels to support connections to third party equipment (e.g. injector/projectors, TV screen, medical gases) have been installed according to the design, before installation of walls and decoration work within the MR Examination room.

Real-world example: Missing RF waveguide was not picked up until building works had completed.

RF waveguides indicated on the original plan were not installed. This omission was not picked up until after the building and decoration of the MR Examination room had completed.

Impact: Avoidable added time & cost associated with installation of RF waveguide: Ramp down MRI magnet, additional work to stud walls to gain access to RF cage, then repairs after waveguide fitted.

Real-world example: Medical gases not replaced

For a replacement MRI installation that involved a new RF cage room, the anaesthetics gases were not reinstalled. It was assumed by MR staff the room that the room was to be refurbished with like for like, but it was unclear if this was included within the design.

Impact: additional costs to retrofit, delays in clinical use

Since confirmation of RF cage performance is made prior to the remaining building & decoration of the MR Examination room and the installation of supporting services, various practical measures are recommended to help avoid unintentionally compromising the performance of the RF cage. These include the following.

- Temporary removal of the RF leaves at the bottom of the MR Examination room door to avoid potential damage arising from opening/closing the door over any trailing cables on the floor immediately outside of the MR Examination room door. Importantly, any such changes to the RF cage need to be reinstated prior to a follow up RF cage check and final handover to the customer.
- Connecting the RF cage to an insulation resistance tester that will generate an audible alarm if a path to earth is inadvertently made during the remainder of the building works. This is strongly advised to immediately flag any such problem, avoiding the potentially very difficult task of identifying them after all the building works have completed.
- Avoidance of any loose metal connections, since these can produce discharges of RF interference, appearing as RF spike artefacts on the MR images and degrading diagnostic quality. The suspended ceiling should be fixed. Suspension via movable clamps or springs should be avoided. Similarly, any cabling in the ceiling void should be fixed to appropriately secure cable trays and mounting brackets. Loose cables trailing on the suspended ceiling within the RF cage as demonstrated in Figure 21 are known to be a source of RF spikes and should be avoided.

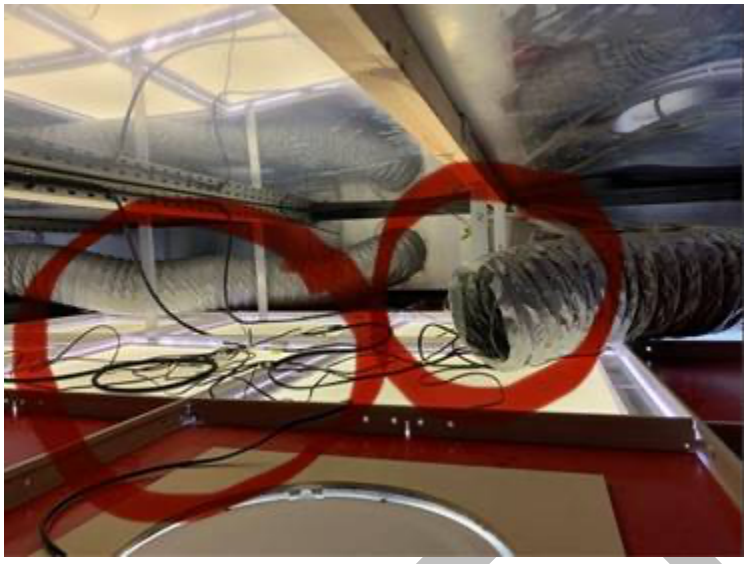


Figure 21. Loose cables trailing on the suspended ceiling within the RF cage are known to be a source of RF spikes and should be avoided by use of secure cable trays and mounting brackets.

Importantly, the use of any ferromagnetic materials/components during the subsequent building works within the RF cage should be avoided, since may subsequently present a subsequent projectile risk when the MRI magnet is ramped up.

Real-world example: ferromagnetic screws used within MR Examination room.

Ferromagnetic screws were used for fixings within the MR Examination room. During a routine inspection of the quench pipe, a ceiling tile bracket was dislodged and was pulled into the MR scanner, narrowly missing the MR engineer and causing some superficial damage to the outer covers of the scanner.

Impact: cost & time associated with ramping magnet down, replacing all ferromagnetic fixings and ramping magnet back up.

Finally, RF cage performance may already have dropped by the time the MRI installation has completed and is ready to hand over to the customer (Small *et al.* 2026). Consequently, consideration should be given to planning for a repeat RF cage test once all building work and installation of the MR scanner has completed to confirm the performance of the RF cage is still appropriate.

4.4 Quench pipe

For MR systems that incorporate a quench pipe, the following steps are recommended to be taken at installation to confirm that the quench pipe has been installed correctly and to support ongoing annual inspections.

- Obtain confirmation from the MR manufacturer that the MRI quench pipe has been installed to their specification.
- Perform a risk assessment if required for accessing locations to visually inspect the quench pipe outlet. Potential mitigations may include introducing a permit to work system for the area immediately around the quench pipe outlet.

- Perform a visual inspection of the quench pipe outlet, taking photographic evidence of the following to support subsequent annual check.
    - Access to quench pipe outlet is appropriately controlled
    - No obstructions to the quench pipe outlet
    - Any rain covers/protective mesh are in place
    - Appropriate signage is in place, e.g. IPEM 2017.
    - Area below the outlet appropriate to mitigate risk of exposure to cryogenic gases in the event of an MRI quench, e.g. open windows, sufficient distance to public spaces.
- Perform a visual inspection of as much of the quench pipe as is practical to do so, taking photographic evidence of the following to support subsequent annual check
    - Insulation
    - Hazard warning tape

Real-world example: Incorrect location for quench pipe outlet

The quench pipe outlet was planned to be located 3 metres above head height, but was fitted 3 metres above ground level.

Impact: additional works to increase height of quench pipe outlet. Minor delay in magnet ramp up and clinical use.

4.5 Build requirements prior to MR scanner delivery

Timely commissioning of items within the build phase of the project is key to help identify issues as early as possible. This is important as missing opportunities to perform any remedial work prior to key timepoints in the project can greatly increase overall delays with an associated greater cost. One of the key timepoints in the project timeline is the delivery of the MR scanner.

Conventional superconducting MR scanners require a connection to power and a chilled water supply when they arrive on site to minimise helium boil off. Consequently, water chillers should be installed and commissioned and all chilled water pipework fully pressure tested and flushed with clean filters prior to MRI delivery. Ideally, any planned backup chilled water supply with the associated changeover mechanism should also be fully installed, commissioned and ready to use if needed by the time of MRI delivery. The mains electrical cable for the MR system should have been pulled and be ready to connect to the MR system.

Installation and commissioning of the RF cage should have completed, including confirmation of expected non-MR manufacturer waveguides and filter panels. An opening in the RF cage will then need to be made, sufficient in size to bring the MR scanner into the room.

The HVAC, including all ductwork, should also be fully installed and commissioned prior to magnet delivery. Additionally, the oxygen monitor should be installed and commissioned, including confirmation that a low oxygen alarm automatically triggers the emergency air extract mechanism from the MR Examination room.

Real-world example: Emergency extract continuously drawing cold air into MR Examination room

During winter, the MR Examination room was impacting on clinical MRI. Eventually, it was identified that the emergency extract system was incorrectly configured and this had not been picked up at commissioning. The emergency extract system was reconfigured to correct operation.

Impact: Reduced capacity and delays to patient scans

MR Examination room lighting should be fully installed and commissioned. Ideally, all fire compartmentation works should also have been completed.

Real-world example: Poor communication between installation parties

An issue with external RF interference and image artefacts was identified to arise from some additional lighting within the MR Examination room lighting aimed at improving the patient experience, but access to the control box was blocked by the subsequent installation of pipework. Consequently, these lights were permanently turned off.

Impact: Unusable lighting system, impaired patient experience

Local network connections and IT firewall changes should be in place to allow the MR engineers to configure remote monitoring of the MR system by the MR manufacturer soon after magnet delivery. Additionally, local connections to the BMS should be operational to help identify any issues with the chiller and supporting plant in a timely manner.

4.6 Build requirements prior to ramping up MRI magnet

Another key timepoint in the project is when the MRI magnet is ramped up, since it is then that all of the risks associated with the large static magnetic field become real and permanent. If the MR system is based upon a permanent magnet, then these risks may be present when the MR scanner is delivered.

Where possible, all building work and installation & commissioning of equipment within the MR Examination room should be completed prior to the MR scanner being ramped up to avoid the need to manage the additional risks of performing work in the presence of the high magnet field. Key items of work to consider include the following.

- In-room storage
- Medical Gases
- Electrical safety testing, including commissioning of any IPS/UPS sockets

It is important that an MR Controlled Access Area should be in place by the time the MRI magnet is ramped up to field. It should be clear who is responsible for the MR Controlled Access Area since this will be prior to handover of the MR system and building work to the MR Responsible Organisation. It is important to confirm the installation of any planned magnetic shielding to avoid the agreed magnetic field threshold extending into areas adjacent to the MR Examination room.

Real-world example: Magnetic shielding in the design was not installed.

Magnetic shielding in the ceiling above the MR Examination room that was included in the design to avoid the B_0 Hazard Area extending into consultation rooms above the MR suite was not installed during the main build phase of the project.

Impact: >£50K additional cost to hospital, 2 month delay to project

Real-world example: steel shielding, specified during design phase, was not installed.

The need for steel shielding to contain fringe field from extending into offices above the MR Examination room was identified during the design phase of the project but was not sufficiently communicated to the installation team.

Impact: Additional costs, plus a 2–3-month delay to ramp down MRI magnet, order and install shielding, then ramp MRI magnet back up.

It may be beneficial to aim for installation and commissioning of any MR Conditional equipment that is intended to be used within the MR Examination room, e.g. anaesthetic machines, power injectors and patient monitoring, to occur before the magnet is ramped up to reduce the impact on needing to screen and supervise installation engineers within the MR Environment once the MRI magnet is at field. Similarly, it may be helpful for installation/commissioning of other items intended to be used within the MR Controlled Access Area more generally, e.g. intercom system and nurse call system. The reader is referred to HBN 06-01 for further information on more general items to consider.

Importantly, the data connection for remote monitoring of the MR system by the MR manufacturer should be confirmed prior to ramping up the magnet, as this can help to ensure timely intervention in the event of a problems relating to/including a magnet quench when MR engineers or MR staff are not on site.

Real-world example: delays in firewall configuration to enable remote monitoring

Network firewall changes required to enable the MRI manufacturer to remotely connect to the MR scanner to monitor its status were not in place when the chiller supporting the MR system developed a fault. The failure of the chilled water supply resulted in the MR scanner losing helium for 4 days before a radiographer visited and discovered the problem. This resulted in over 200 litres of helium being lost.

Impact: hospital had to cover costs for replacement helium

Finally, any floor sealing and a deep clean of the MR Examination room is recommended immediately prior to magnet ramp up to avoid the need to use to non-ferromagnetic equipment. The clean may be helpful to remove any ferromagnetic swarf or other particulates that may have been introduced to the room, e.g. via contractor's clothing or footwear.

If ongoing building works are still ongoing when the magnet is ramped up it is recommended to install a tack mat in the MR Examination room doorway, if not already in place, to capture dust and dirt and help minimise the introduction of further ferromagnetic particles into the MR Examination room.

4.7 Summary & checklist

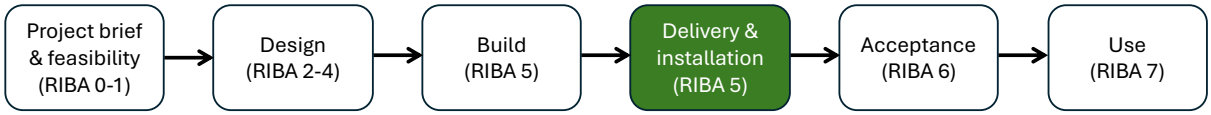
RF cage	✓
All specifications from the RF cage manufacturer have been met, e.g. slab depth, flatness, dryness?	
RF cage attenuation measurements completed and within MR manufacturer's specifications?	
All planned waveguides and filter panels to support connections to third party equipment have been installed before the installation of walls and further building work within the MR Examination room?	
Consideration of temporary measures to avoid/identify inadvertent damage to RF cage during remainder of building/installation works?	
Insulation resistance tester in place to immediately indicate if electrical connections to earth are inadvertently made?	
Loose metal connections are appropriately secured, e.g. cable trays?	
Consideration of repeat measurement of RF cage performance after all building and installation works completed?	
All fixings within the MR Examination room are non-ferromagnetic?	

Quench pipe	✓
Received confirmation from the MR manufacturer that the MRI quench pipe has been installed to their specification?	
Risk assessment completed if required for accessing locations to visually inspect the quench pipe outlet?	
Documented visual inspection of the quench pipe and quench pipe outlet to support subsequent annual inspections?	

Requirements prior to MR scanner delivery	✓
Required power supply for MR system in place?	
Chillers installed, commissioned and ready for connection to MR system?	
If specified, backup chilled water system installed, commissioned and ready for use?	
If required, quench pipe installed and confirmed to meet MR manufacturer's requirements?	
HVAC installed and commissioned	
Oxygen monitor installed and commissioned, including confirmation of automatic triggering of emergency air extract by oxygen alarm?	
MR Examination room lighting should be fully installed and commissioned?	
Data connection for remote monitoring in place?	
BMS connections to supporting plant operational?	

Requirements prior to ramping up MRI magnet	✓
All storage within MR Examination room built/installed?	
Medical gases installed and commissioned?	
Electrical safety testing completed?	
MR Controlled Access Area in place, with clear allocation of responsibilities?	
Any planned magnetic shielding installed?	
Installation and commissioning of any MR Conditional equipment that is intended to be used within the MR Examination room?	
Confirmation by MR manufacturer of working remote monitoring?	
MR Examination room floor sealed?	
Deep clean of the MR Examination room?	
Installation of tack mats at entrance to MR Examination room?	

5 Delivery & installation (RIBA stage 5)



5.1 Introduction

This section covers the delivery and installation of the MR system. Although both this and the previous build section are part of RIBA stage 5, they are separated here since in the context of new MRI installations they form two distinct pieces of work.

Use of the term MR Installer in this section recognises that for some new MRI projects the MR manufacturer may subcontract installation of the system to a separate team. Additionally, the MR system may be purchased from another supplier.

Ideally the majority of the building work will have completed by this stage of the project. However, there will typically be a need for some overlap to reseal the RF cage and complete the build and decoration of the MR Examination room. Consequently, it is important to consider and agree how site responsibilities will be managed between the MR Installer and other contractors.

It is important to establish schedules with all parties concerned in the early stages of the MR installation. Examples of items that might appear in the schedule of work for the delivery and installation phase are listed below in Table 4.

Activity	typical duration [days]	Comments
MR scanner and associated equipment delivery including liquid helium	1	Note: local Council should be notified in advance and permission obtained for any road closures required for delivery of MR scanner if applicable
Internal cabin finishing works	1-2	Make good post delivery. Refit RF cabin scanner entry panels
Helium fill	0.5	To suit manufacturer's programme
MRI Scanner installation, ramp up & commissioning period	4-8	Once the MR scanner is ramped up permits to work should be issued (MR) and MR Safety screening of contractors/Trust staff accessing MR controlled areas
Network connections (PACS + remote monitoring)	1-2	Integral with MRI commissioning

Installation of ancillary equipment e.g. contrast injector	1-2	Consider this prior to MRI ramp up. Also check any dedicated enabling requirements (power, data, structural mounts, etc)
Cleaning of MR suite	1-2	To meet local requirements

Table 4. Examples activities associated with delivery and installation phase.

5.2 MR scanner delivery

Conventional superconducting MR scanners are not ramped up during transit and therefore the hazard of the large magnetic field is not present. Consequently, the requirements for delivering MR systems are generally similar to those associated with the delivery of other large items of equipment. Sites should follow standard practice and recommendations for such deliveries. Typically, the MR Installer will organise and manage many of the aspects associated with the MR scanner delivery. Specific points to consider include the following.

- Structural capacity for delivery/exit route within the building
- Structural capacity of the proposed location for the crane & all approvals to erect
- Hospital approvals. Potential impact on any hospital services/other departments should have been discussed well in advance, mitigations considered and plans agreed well in advance of the proposed delivery date.
- Council/other external approvals, e.g. any public road closures required for cranes to remove/deliver the magnet should have been approved in advance by the local council. Consider also requirements for any crane jib or load over-sail of property not under the control or ownership of the main contract or its agents.
- Forming delivery/exit apertures for MRI
- Forming scaffold/platform for MRI exit/delivery

MR systems based on permanent magnets may pose additional logistical challenges for delivery in terms of increased weight compared to superconducting magnets, as well as the permanent magnetic field. Non-ferromagnetic alternatives may be required for many of the tools typically used to rig the MR scanner. The benefit is that there are no cryogens and therefore no need for quench pipes or a continuous water cooling system. Typically, there is also only one cabinet that comes with the system that requires power.

Real-world example: Late change in delivery route for MR scanner

Permissions for the original proposed delivery route were not obtained, and an alternative delivery route had to be arranged at short notice.

Impact: Additional cost

If included in the design, MR scanners should be placed on MR manufacturer approved anti-vibration pads at their final location in the MR Examination room. Super-conducting MR systems will require connection to the dedicated chilled water supply at delivery to ensure minimal helium boil off.

5.3 MR scanner installation

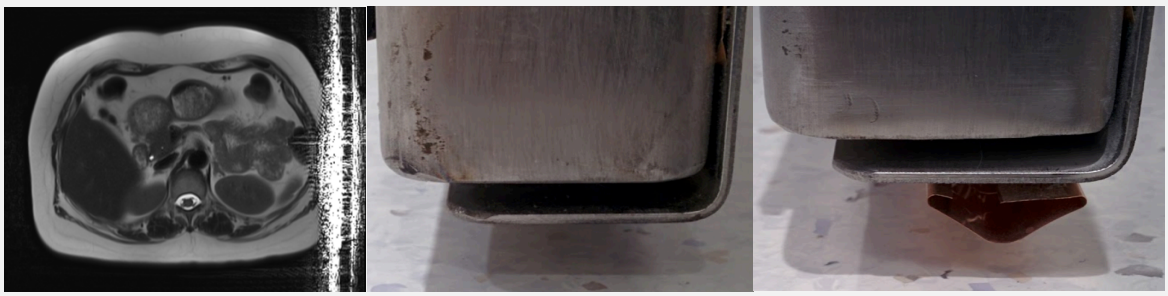
The installation of the MR scanner will typically be performed dedicated MR installation engineers. They will generally be very experienced with the installation of MR systems and be able to manage appropriately any potential issues that might arise. Consequently, this section focuses more on a few issues that may be helpful for the MR Responsible Organisation to consider.

Adjacent MR scanners at same field strength

In the event that an MR scanner is installed adjacent to another scanner operating at the same nominal static magnetic field strength, it is generally advisable for the MRI engineers to utilise the permitted windows of ramped up field strength to maximise the difference in final static magnetic fields between the two systems. This helps to avoid the potential for RF signal emitted by one MR scanner being detected by the other (and vice versa) and negatively impacting on the image quality. However, even when such a separation is performed, there may still be overlap in RF frequencies when MR images acquired with a high receiver bandwidth and image artefacts can result if RF cage performance is insufficient.

Real-world example: RF interference from nearby MR scanner at same field strength

Two 3T MR scanners were installed with a shared MR control room. Although the MR scanners were ramped up with the appropriate separation of centre frequencies, intermittent external RF interference was observed on MR images with high receiver bandwidths. It was subsequently identified that the metal strip at the base of the MR Exam room door that formed the electrical connection with the door frame was missing. This had been removed after the RF cage was built and commissioned to avoid potential damage to this strip during the rest of the building work, but reattaching this had been missed.



Impact: reduced MRI quality until RF leaves reattached on MR Examination room door.

Confirmation of working remote monitoring

Sites are encouraged to seek confirmation from the MR Installer/MR manufacturer that any planned remote monitoring is working as expected. This is encouraged as soon as possible after the MR scanner is connected to the local IT network to help mitigate for problems that may arise out of hours, in particular any problems with the chilled water supply or a magnet quench.

Real-world example: Non-functioning remote monitoring system not followed up.

Remote monitoring of MR system was discovered to be partly/non-functional many months after installation had completed.

Impact: Increased consequences should problems have arisen with cooling for the MR system out of hours, potentially resulting in significant periods of downtime if system had quenched.

MR system local IT configuration

Configuration of the MR system with regards local network connections (PACS, RIS worklist, other DICOM nodes) and remote monitoring is typically set up by the MR Installer in conjunction with the Trust PACS/IT team. Local sites are encouraged to confirm local IT configurations are completed as requested. This should include end-to-end testing to confirm a complete patient workflow, i.e. registering a test patient on the RIS, pulling details across to the scanner, scanning a test object and archiving images to PACS. Where specified, retrieval of MRIs from PACS should be confirmed. It may be helpful to confirm any changes in DICOM metadata when retrieving items from the PACS. Additionally, confirmation of MRI transfers to each specified DICOM node is recommended.

MR system commissioning

Following magnet delivery and installation the MR Installer will run a series of commissioning procedures and tests. These include shimming, tune up, quality assurance (QA) tests and coil QA. The MHRA recommend that the manufacturer or supplier provides written evidence that the equipment is compliant with the procurement specifications and their own performance specifications, and suggest it may be helpful for a hospital technical representative to be present during commissioning procedures.

Control of access

Prior to the magnet being ramped up it's important for the MR Safety Expert to liaise with the MR Responsible Personn/lead MR radiographers to ensure designation of the MR Controlled Access Area, appropriate display of MR Safety notices and that any personnel working in MR Controlled Access Area e.g. contractors, Estates staff undergo MR Safety screening. It is recommended that any areas within the B_0 Hazard Area outside of the MR suite or areas close to the quench pipe outlet are now classified as permit to work areas.

Typically, MRI installers will provide MR Safety signage as per recommendations in IEC 60601-2-33. However, local MR units & Medical Physics teams may prefer to utilise alternative/additional signage, e.g. IPEM MR-Safety Notices (IPEM 2017).

5.4 Ancillary equipment installation

Ancillary equipment is not always supplied in one process by the magnet installer, so this may arrive anytime during or sometimes post installation with other responsible parties for installation. It is important that any ancillary equipment is tested and labelled as MR Safe, MR Unsafe or MR Conditional with conditions attached. Consider any services or enabling works that may be needed for such equipment within the overall project plan.

5.5 Summary & checklist

MR scanner delivery	✓
All approvals obtained for MR scanner delivery, including crane location, delivery route, any required road closures?	
All enabling works for MR scanner delivery completed, including formation of access route into the building and any required scaffolding?	
MR scanner placed on anti-vibration pads in MR Examination room?	
MR scanner connected to chilled water supply?	

MR scanner installation	✓
Separation of centre frequencies for adjacent MR scanners at same nominal field strength?	
Confirmation of fully operational remote monitoring from MR Installer/MR manufacturer?	
Confirmation of MRI IT configurations as specified?	
Confirmation from MR Installer of completed commissioning of MR system?	
Confirmation of working access control to MR Controlled Access Area?	
Confirmation of installed additional MR Safety signage specified by MR Responsible Organisation	

2766

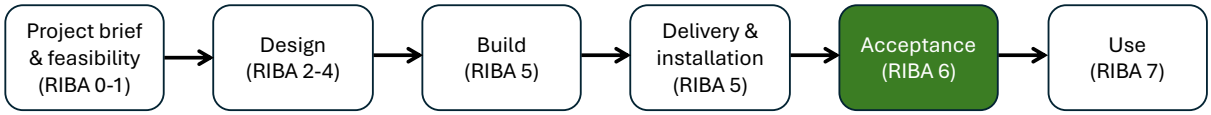
2767

Ancillary equipment installation	✓
All ancillary equipment (e.g. pump injector, infusion pump, GA machine etc.) commissioned and displays appropriate MR Safety labelling	

2768

2769

6 Acceptance (RIBA stage 6)



6.1 Introduction

This section covers the acceptance phase of a new MRI installation. Acceptance testing covers the process of checking that the installation and the performance of the equipment are as expected. It is performed on behalf of the MR Responsible Organisation to inform a decision to accept the work and formally take on responsibility from the MRI manufacturer and/or installation provider. Additionally, acceptance testing provides baseline measurements for any subsequent checks, e.g. as part of regular quality assurance programme.

Discussions here are focussed on items that are considered to have additional/specific relevance for MR suites. For more general, non-MRI specific items, please refer to HBN 06-01. For acceptance of the MR system, acceptance should only commence once the MRI manufacturer has completed the installation and commissioning of the MR system and believe it is ready for use. Ideally all building works should also have completed prior to acceptance testing.

Project teams are encouraged to plan for independent acceptance testing of the MR scanner by a suitably qualified MR physicist. There are many examples where despite the completion of MRI manufacturer's own commissioning, items are inadvertently missed. Additionally, it is important to factor in an appropriate time into the project plan for acceptance testing.

This guidance does not include any recommendations on specific imaging acceptance checks. This is anticipated to be the subject of future work. In the meantime, the reader is referred to guidance on MRI QA, such as IPEM report 112 (IPEM 2017a).

6.2 Non-imaging acceptance test checks

A list of non-imaging acceptance test checks relevant to a typical MRI installation is provided below in Table 5. These should be considered in addition to items on the Build (4.7) and Installation (5.5) checklists that have not been completed.

Check	Essential/ Possible	Suggested acceptance criteria
Delivery and commissioning of all ordered RF coils?		As ordered
Installation of all ordered software licences/packages?		As ordered
Confirmation that all commissioning work has been performed and has passed		All commissioning completed
Detachable Table undocks in emergency?	Essential if applicable	Undocks/redocks
MR Conditional Trolley	Essential if applicable	Present and labelled
Patient communication system	Essential	Functional
Patient alarm	Essential	Functional

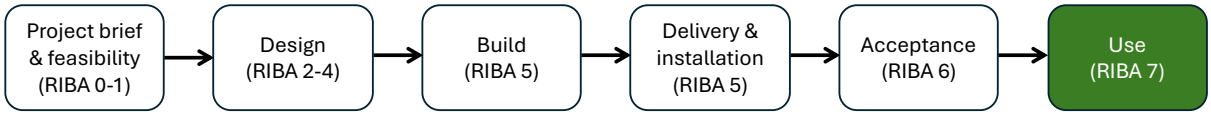
Check	Essential/ Possible	Suggested acceptance criteria
RF Door opens/closes and locks	Essential	Checked
RF cat flap opens/closes easily	Essential if applicable	Checked
CCTV camera if installed as an extra	Possible	Installed and operational
Check extent of relevant fringe field values	Essential	B_0 Hazard Area does not extend into uncontrolled areas
Acoustic Noise	Possible	Noise levels acceptable in adjacent occupied spaces
RF Cage Attenuation check	Possible	RF Cage installers to demonstrate performance after full installation or independent check of RF cage performance. Copy of RF cage certificate suppled to local Physics team.
For MR systems with quench pipe: risk assessment for accessing locations to visually inspect the quench pipe outlet.	Essential	Checked
Manufacturer phantoms	Essential	Checked as present
Spill kit for phantoms Relevant COSHH forms completed	Essential	Checked as present
Power to auxiliary equipment available	Essential	Checked as functional
Music/video/lights	Possible	Checked as present and functional
Warning signs for entrances to MR Environment and MR CAA	Essential	
Display plots of relevant fringe fields associated with static magnetic field	Essential	
MR Safety labelling of devices/ancillary equipment	Essential	Checked as present with correct conditions on label
Floor markings of magnet field isocontours for MR Conditional ancillary equipment	Possible	
Systems of work for roof/basement	Essential where required	Written/signed off
Medical gases - prep area and MR Examination room. Scavenging outlet- all tested and signed off by medical physics/estates/gas specialist and commissioned.	Essential if applicable	Checked as present and functional
Policy for out-of-hours emergency access lodged with Security/Fire Department	Essential	Policy written and signed off
MR Safe/MR Conditional ladders in technical room	Essential	Checked as present
Display panels in control room wall for oxygen sensor/chilled water flow/chilled water temperature and phase fault errors	Essential	Checked as present

Check	Essential/ Possible	Suggested acceptance criteria
Appropriate labelling next to all display panels/alarms. This may include the following descriptions. • What is it. • What is expected if working as intended, e.g. no alarm, normal range of values. • Who and to contact if alarming/outside expected values, and how to contact them.	Essential	Checked as present
MR Examination room temperature and humidity monitor.	Essential	Checked as present
Quench buttons	Essential for superconducting MR system	Present and confirmed functional by manufacturer
Emergency power off buttons	Essential	Checked as present
All emergency buttons/ features labelled (what is it?, if values are displayed, what values are expected (e.g. for humidity levels)?, who to contact if alarming/outside expected values?)	Essential	Checked as present
Patient Lockers	Essential	Checked as present and functional
Liaison/visits with other teams who may need to access MR Controlled Access Area to explain safety - Resuscitation - Security - Domestic Services - Fire Brigade	Essential as required	Done
MR Conditional ladders in technical room	Essential	Checked as present
MR Conditional Fire Extinguisher	Essential	Present, checked as MR Conditional and labelled

Table 5. List of non-imaging acceptance test checks relevant to a typical MRI installation.

Once the magnet has been installed, commissioned and acceptance tested, all building works including final touches have been completed, and reports/evidence has been submitted to the project team and Trust then the scanner and building can be handed over to the Trust.

7 Use (RIBA stage 7)



7.1 Introduction

This section covers the use of the new MRI installation, from when it is formally accepted and lasting for the lifetime of the system. Those involved in Facilities and Assets Management support the users of the MRI department and there should be close working relationships with the MR Responsible Person and the MR Safety Expert throughout the lifetime of the building.

7.2 Policies and procedures

The MR Responsible Organisation should have appropriate policies and procedures in place to support safe working practices within the MR suite and ensure high quality services. Various guidance and resources are available to support on this, including the following.

- MHRA guidelines for MRI safety (MHRA 2021)
- SCoR-BAMRR guidelines for safety in MRI (SOR-BAMRR 2019)
- A list of all SCoR guidance covering MRI (SoR)
- Quality Standard for Imaging (CoR-RCR 2024)

The MHRA also provide guidelines on the management of medical devices more generally (MHRA 2021a).

Regular audits of current practice against local policies and procedures, and additionally of local policies and procedures against national guidance, are encouraged to help ensure up to date high quality and safe working practices. Audits are considered to be one of the seven pillars of clinical governance.

7.3 Preventative maintenance.

Regular preventative maintenance and servicing of the MR scanner and supporting plant is key to addressing issues in a timely manner, ideally before they impact on the MRI service. There are various examples, particularly with chillers and other supporting plant, where a lack of appropriate preventative maintenance has resulted in failures that have led to significant downtime of the MR scanner.

A plan for how service engineers will access certain areas when on site, e.g. MR Controlled Access Area, MR Tech room, chillers, AHU, to allow them to carry out their work should be implemented. Co-ordination of preventative maintenance visits may be helpful to minimize impact on the MRI service, e.g. arranging for chiller service visits (that may require periods of chiller downtime) to coincide with MR system service visits.

Chillers

As part of business continuity planning, sites may wish to consider options to hire a temporary chiller to support the MR system, particularly if there is no back up option.

Real-world example: Mobile chiller hire

Following breakdown of the chiller support for the MR system, a temporary chiller was hired. This was delivered and installed within a few hours, allowing the MR system to be used.

Impact: MRI downtime limited to a few hours

MR Examination room doors

A preventative maintenance programme associated with the MR Examination room door is recommended to help avoid various issues that include the following.

- Repairing of broken RF leaves to maintain RF cage integrity (Small *et al*. 2026)
- door mechanisms latches and locks are in full working order, reducing the risk of patients and staff becoming trapped within room (Steckner *et al*. 2026)
- doors becoming overly difficult to open and close, which may present a manual handling risk (Steckner *et al*. 2026). Additionally, this may result in practices where the MR Examination room door is not appropriately closed during MRI scanning which may result in external RF interference impacting image quality.

Periodically cleaning the RF leaves and magnet door frame with alcohol-based wipes can help reduce residue build up that may impact on electrical contact and RF cage performance. One of the RF cage manufacturers recommending cleaning the door frame around every 2 months for maximum performance.

Real-world example: RF cabin door hard to open/close.

Broken door handles due to MR Examination room RF door slamming. Poor MR image quality due to MR Examination room door not completely closed during scans

Impact: additional costs and poor image quality

Non-ferromagnetic fire extinguishers

If the servicing of non-magnetic fire extinguishers within the MR suite is incorporated into a site-wide servicing programme, care should be taken to ensure that there is a clear recognition of any non-ferromagnetic extinguishers and the need to maintain them as non-ferromagnetic.

Real-world example: Fire extinguishers within MR suite were not sufficiently identified as non-ferromagnetic as part of hospital-wide servicing programme.

Non-ferromagnetic fire extinguishers within the MR suite were inadvertently swapped out for standard ferromagnetic fire extinguishers as part of a site-wide servicing programme for fire extinguishers within the hospital.

Impact: the introduced conventional ferromagnetic fire extinguishers presented a significant projectile risk if taken into the MR Environment.

Generator testing

For MR systems on generator supported secondary power supplies it is highly recommended to plan for planned generator testing. A sudden loss of power to the MR system can result in errors that can subsequently lead to significant down time. In 2022, there were 3 cases of generator testing impacting on MRI reported to NRLS.

Quench pipe inspections

The MHRA guidelines for MRI safety recommend annual inspections of all vent piping. This should include, at least, a visual inspection of the external piping. Additionally, the quench pipe outlet should be visually checked after periods of extreme weather. Responsibility for checks on the quench pipe sits with the MR Responsible Organisation.

Specific recommendation on steps to perform following installation are provided in the Installation section to establish a baseline. The following steps are recommended to be taken on an annual basis, which may form part of a more general MR Safety audit.

- Review and update as required any risk assessment for accessing locations to visually inspect the quench pipe outlet.
- Perform a visual inspection of the quench pipe outlet, taking photographic evidence of the following to check/confirm no changes since previous check.
    - Access to quench pipe outlet is appropriately controlled
    - No obstructions to the quench pipe outlet
    - No changes to any rain covers/protective mesh
    - No changes to signage
    - No changes to area below the quench pipe outlet that might increase the risk of exposure to cryogenic gases in the event of an MRI quench.
- Perform a visual inspection of as much of the quench pipe as is practical to do so, taking photographic evidence of the following to confirm no change since installation
    - Insulation
    - Hazard warning tape

Emergency ramp down unit

The magnet emergency run-down unit (emergency quench button) will usually contain a backup battery. Some MR manufacturers provide users with the ability to periodically check this backup battery.

Drip trays

Ideally any drip trays that are installed, e.g. in tech room, will be installed with a direct connection to drain. If this is not the case, then periodic checks of trays are recommended to avoid overspilling.

Oxygen monitors

Conventional oxygen monitors are based on an electrochemical sensor that typically starts to fail after about 2 years, at which point a low oxygen state will be triggered. Regular replacement of the oxygen sensor as part of a preventative maintenance is therefore key to avoiding false alarms. Servicing of oxygen monitors should be performed by qualified individuals.

Real-world example: Automatic trigger of emergency extract inadvertently disabled when oxygen monitor serviced by a non-trained individual.

The chemical sensor for an oxygen monitor was replaced by a member of staff, who inadvertently disabled the automatic trigger of the emergency extract fan when the oxygen alarm was triggered.

Impact: MR suite was operating for an extended period of time with no automatic trigger of emergency extract when low oxygen alarm triggered, impacting the health and safety of staff and patients. Subsequently servicing of the oxygen monitor was contracted out to specialist company.

Confirmation of a working automatic trigger of the emergency air extract for the MR Examination room is recommended as part of preventative maintenance checks.

It may be helpful to procure a portable oxygen sensor for an MR suite to utilise in the event of a suspected false oxygen alarm.

7.4 Changes within the MR suite

The MR Responsible Person should be included in the procurement of any new equipment for the MR suite. Some items of MR Conditional ancillary equipment may require modification of the MRI MR Examination room floor to demarcate areas of high magnetic field where the device may not enter. Tethers may also be required to limit movement in the MR Examination room. Some MR Conditional equipment requires testing in the MR scanner sound while the scanner is imaging to rule out mutual interference. Advice should be sought from the MR Safety Expert.

If a change of usage of the MRI department is proposed, e.g., anaesthetics, paediatrics, compartmentalisation of MRI department to limit aerosol producing procedures (COVID-19), MR-guided biopsy, radiotherapy, MR-autopsy, etc… a detailed plan should formulated with all the relevant parties consulted.

7.5 Changes outside of the MR suite

Changes near the new MR suite can have negative impact on the functionality of the MR scanner. The movement/installation of large ferromagnetic items (e.g., cranes, scaffolding, new lifts, air ambulance) nearby can alter the highly homogeneous magnetic field of the MR scanner, potentially affecting patient images.

Installation of other equipment in the vicinity (both in-floor and through-floor) should also be carefully considered as they may have a sensitivity to elevated magnetic fields (e.g., gamma camera, fluoroscopy systems, cyclotrons, linear accelerators, CT scanners, other MR systems). Magnetically guided surgical equipment may require installation more that 30m distance from an MR scanner.

It is important to maintain an access route to the MR scanner for servicing that can accommodate the replacement/delivery of large items such as a gradient coil and helium dewars. For conventional superconducting MR systems, in the event of a magnet quench it is typically important for a helium refill to occur as soon as possible to avoid the magnet warming up the point where a thermal cycle is required. This is particularly important for 3T and higher field systems. One MR manufacturer reports a 24-hour window of opportunity to deliver helium to stabilise a 3T system and avoid a thermal cycle.

Real-world example: Access route to MR scanner for servicing not maintained

When a gradient coil on an MR scanner needed replacing, it was found that building work outside the MR suite that had occurred after the MR system was installed had restricted physical access, leaving insufficient space to remove and replace the coil.

Impact: Additional building work required to restore access for replacement of gradient coil

Any building changes in the vicinity of the quench pipe outlet should first be discussed with the MR Responsible Person. Air intakes, doors and windows are a particular concern. Workers in this region should be aware of cryogen hazard and know how to respond in the event of a quench. Following any quench, a thorough inspection of the cryogen vent system should be conducted prior to returning the MR scanner back to service. Any modifications of quench pipe system may be subject to the Pressure Systems Safety Regulations (2000). Close consultation with the MR Safety Expert and the MR Responsible Person is strongly recommended when any changes are proposed within or in the vicinity of the MRI department or quench pipe.

Finally, it is important to consider maintaining options for future removal/replacement of the MR scanner, including the locations where a crane or scaffold are placed to enable this change.

7.6 Adverse incident reporting

A structured incident reporting system is important to enhance MRI patient safety by strengthening the overall safety culture and providing staff with a reliable mechanism to document adverse incidents, near misses, and unsafe conditions. Reliable incident reporting depends on a strong organisational reporting and learning culture. It also requires standardised methods for reviewing and coding incidents, timely feedback to staff on outcomes and lessons learned and follow-up, to ensure that corrective actions are fully implemented. Learning from analysis can be shared to promote system-wide learning with a focus on processes rather than individual blame. This in turn can help to drive continuous improvement through updates to policies and procedures, training, and system design. By consistently reviewing and learning from incidents, MRI services can create a safer environment for both patients and staff.

Services are encouraged to adopt the UKHSA national coding taxonomy for MRI-related incidents and near misses (UKHSA 2024). Using a single, standardised coding framework allows services to identify system-level issues, reduce variability, and enhance safety strategies across MRI practice. Further information on submitting data to the national incident learning system can be found on the Medical Exposures Group webpage. Submitting coded MRI incident data to UKHSA will contribute to the following.

- A national overview of MRI safety events
- Enable services to benchmark their own trends
- Development of effective, evidence-based improvements across the sector

This is a voluntary incident learning system and does not negate the legal requirement to report to the relevant regulatory authorities.

7.7 Replacement/decommissioning

A route for eventual replacement of the MR system should be maintained as part of the building maintenance strategy, typically authored by the architects, and the site development control plan. This should include all aspects of the replacement, e.g. crane placement.

Real-world example: replacement route for MR scanner not maintained.

The original route for transferring the magnet into the building was not protected. When it came to subsequently replace the MR scanner, a new route had to be established requiring removal and subsequent replacement of section of the hospital façade.

Impact: about £70K of additional costs

The MHRA's guidance on the management of medical (MHRA 2021a) provides advice regards planning for device replacement and eventual decommissioning and disposal. These include suggestions for replacement criteria, appropriate secure deletion of any patient identifiable data and guidance on potential sale of medical device or donation for reuse. Global Health Partnerships, a UK charity and international development organisation, also provide UK-specific guidance on medical equipment donations (Mullally S, 2013).

The MR manufacturer may be able to provide information about the current performance of an MR system relevant to considerations about replacement/upgrade. This may include metrics on how performance has changed during the lifetime of the system, as well as comparisons with similar systems and with new generations of MR scanner.

7.8 Summary & checklist

Policies and procedures	✓
Local policies and procedures in place?	
Regular audits?	

Preventative maintenance	✓
Preventative maintenance in place for the chillers?	
Preventative maintenance in place for the MR Examination room door?	
Non-ferromagnetic fire extinguishers are appropriately recognised in any site-wide servicing programme?	
Annual inspection of all MRI quench pipes?	
Periodic check of magnet quench backup battery (if applicable)?	
Periodic check of any drip trays not connected to drain?	
Preventative maintenance in place for oxygen monitors?	

Changes within the MR suite	✓
MR Responsible Person included in the procurement of any new equipment for the MR suite?	

Changes outside of the MR suite	✓
Access route to MR scanner for servicing is maintained?	
Access route for future removal/replacement of the MR scanner is captured as part of long-term site plan to ensure this is considered when any building projects are planned that may impact on the MR scanner or be impacted by the MR scanner?	

Adverse incident reporting	✓
Adoption of UKHSA national coding taxonomy for MRI-related incidents and near misses?	

Replacement/decommissioning	✓
Replacement of the MR system is maintained as part of the building maintenance strategy, and the site development control plan?	

8 Examples

"Fly on the wall" accounts of two MRI installation projects are provided here as examples of firstly, what was considered to be a good example, where the project was well organised and progressed smoothly, and secondly an example where several issues were identified in hindsight.

8.1 Example 1

This Fly on the Wall account is for an installation of a replacement MR scanner where the project progressed smoothly. The project team included Project Manager, Head of Radiology, Trust Project Manager for Estates, MRI Lead Radiographers, representatives from Clinical Engineering, MRI Physics, MRI manufacturer, building contractors and a company who had recently installed a new façade to the hospital. The PACS team were also consulted.

September

There was a slight delay in getting the Turnkey orders on the procurement system but the manufacturer had now received the order and the project management team (external to Trust) were putting a programme together for the replacement of an existing MR scanner.

October

- A provisional programme, including a Gantt chart and proposed plan of the MR Suite, had been issued subject to confirmation of dates for the (expensive) removal and reinstatement of a Façade on the front of the hospital. This was required to remove the existing MR scanner from the second floor and deliver the new MR scanner once building works had progressed. MRI Physics queried the change to an inward opening door to the scanner room on the proposed plan. However, the direction of the RF door swing couldn't be revised as previously requested and shown on the manufacturer's drawing, as the vaulted ceiling soffit outside the MR Examination room would obstruct the door opening. Options for pressure relief and escape provision were to be explored.

Late October - Pre-commencement Meeting Part 1

The first of several virtual meetings had been scheduled. Attendees included Project Manager, Head of Radiology, Trust Project Manager for Estates, MRI Lead Radiographers, representatives from Clinical Engineering, MRI Physics, MRI manufacturer, building contractors and the façade company.

On the Agenda:

- Cladding Enabling Works and Programme
- Order/Lease – provisional sums for medical gases, fire alarm works, nurse call, chiller replacement, ceiling lighting panels/mood lighting, ventilation works and new injector.
- Contract Dates and Contract Documentation – building works contracts & cash flow forecast to be issued
- Vacant possession of site and scanner removal survey – dates for erection of scaffolding and clearing of site
- Programme/Progress
- Detailed design – surveys undertaken, direction of scanner room door swing (inward) discussed
- Approval of Layouts – dates for final system layout drawings
- Insurances – manufacturer and contractors insurance details to be issued
- Planning and Building Regulations
- Fire Office Comments – confirmation of no compartment walls in MR Suite

- MRI Physics – RF cage test and proposed commissioning dates
- Infection Control Measures - details of infection control lead to be shared
- CDM regulations – F10 required and to be issued by building contractor. Contractor rules, permits, isolation induction requirements and other site considerations to be issued. Fire heat detectors (not smoke) to be fitted for duration for works. Construction Phase (H&S) Plan to be issued prior to commencement
- Site Rules and Restrictions – to be issued
- Access to Site, Storage, Security, Site Compound and Access to Live Hospital Areas - not discussed
- Emergency Contact Numbers - to be included in Project Directory and contractor information pack.
- Cessation of Work – key staff identified and procedures discussed
- Distribution of Documentation – staff circulation list identified
- Any Other Business
- Date of Next Meeting

Early November - Pre-commencement Meeting Part 2

The second virtual meeting had been scheduled. Attendees included Project Manager, Head of Radiology, Trust Project Manager for Estates, MRI Lead Radiographers, representatives from Clinical Engineering, MRI physics, MRI manufacturer, building contractors and the façade company.

On the Agenda:

- Site/survey - visit being arranged, liaising with Trust Estates
- Cladding removal – manufacturer to arrange ramping down mid-November. Building contractors to arrange delivery of scissor lift. Storage of cladding material to be discussed
- Layout drawings – extent of B_0 Hazard Area noted and accepted. No requirement for additional steel shielding.
- Electrical drawings to be issued, mains supply to MR suite and scanner and cabling discussed
- Mechanical design – survey on dates confirmed. Chiller position, routes and requirements for chiller swap discussed. Replacement of the existing ventilation/air conditioning serving the MR suite but power supply to be reused. Drawings to be issued.
- RF cabin – checking with supplier re pressure relief options
- Trust Estates to issue standard contractor's pack
- Head of Radiology has issued project reference number for use on all communications
- RF cabin delivery date confirmed. Check size of delivery vehicle in advance.
- Internal wall being removed as part of the Technical Room – although identified as non-load bearing it also appears to be reinforced concrete, so it is necessary to assess how quickly this can be removed and the amount of disruption. Neighbouring team to be made aware of likelihood of disruption.

Late November

- Electrical design drawings and architectural designs have been issued for comment and approval. Clarity requested for:

1. Suspended ceiling type and tile
2. Door type and finish plus ironmongery
3. Laminate finishes for fitted furniture and worktops etc.
4. Floor finishes – type and colour reference
5. Paint finishes – type and colour reference

- MRI Physics to review the field plots and confirm if they look acceptable and give thoughts to any additional MR Safety Notices required.

- Exception report required for injector as whole life costs are more expensive than originally budgeted for.

Early December - Progress Meeting 1

The first progress meeting is held. Attendees include Project Manager, Head of Radiology, Trust Project Manager for Estates, MRI Lead Radiographers, representatives from Clinical Engineering, MRI Physics, MRI manufacturer, building contractors and the façade company

On the Agenda:

- Matters Arising from Previous Minutes
    - Scaffolding and site accommodation is in place.
    - MRI platform design for magnet removal being double checked by scaffolder and verified by structural engineer.
    - Deadline for energising of a fully terminated and tested electrical supply being provided by the Trust identified.
    - Contract sums issued.
    - RF cabin design will be updated following survey
    - Cash flow forecast issued
    - No issues reported with site establishment
    - Manufacturer & contractor latest insurance details issued
    - Electrical designs issued, comments received relating to emergency lighting to be addressed.
    - RF cabin test dates to be advised
    - Medical Physics acceptance testing dates to be shown on project programme
    - Copy of F10 (HSE project approval) form to be displayed on site
    - Personnel inductions to be done by Trust Estates before undertaking site specific inductions
    - New H&S file to be issued at project completion
    - Trust's contractor rules document issued
    - Asbestos information has been issued. Extent of survey to be reviewed against finalised mechanical services specification
    - Internals walls have been evaluated, and non-percussive methods are to be utilised for concrete cutting.
    - Further site survey of mechanical services has taken place
    - Mechanical design – to be issued for comment and further revised when chilled water scope is agreed.
- Contractor's Report – issued and attached to minutes of meeting
- Contractor's Queries and/or Requests for Information- Finishes samples to be delivered to site this week for selection
- CDM Regulations - safety audits and copies of all reports requested
- Any Other Business - site visits confirmed, social distancing to be observed.

Mid-December

- Site survey completed and RF cabin drawings updated
- Air flow test report issued

- Pressure relief panels to be installed in the MR scanner room ceiling. Design to meet MHRA Guidelines for MR equipment manufacturers protections which are: -
    - the cryogen ventilation path (quench vent),
    - an active emergency extract fan,
    - a passive overpressure relief (exclusive of the RF door), built into MR installation requirements.

Early January - Progress Meeting 2

The second progress meeting was held. Attendees included Project Manager, Head of Radiology, Trust Project Manager for Estates, MRI Lead Radiographers, representatives from Clinical Engineering, MRI Physics, MRI manufacturer, building contractors and the façade company

On the Agenda:

- Matters Arising from Previous Minutes
    - Dates for cladding reinstatement to be confirmed
    - Scaffolding has been removed
    - Scanner delivery date confirmed. Survey to be arranged and RAMS to be issued.
    - Electrical report was issued, review concluded new mains cable and earth are necessary – to be arranged by the Trust
    - Revised scope of chilled water works to include removal and offloading of existing chiller and installation of new chiller to serve the MR scanner being delivered in this phase has been instructed.
    - Detail regarding the scope of ventilation works was issued earlier this year and subsequently reissued. Further detail for HTM derogation to be provided.
    - Response provided to Estate's comments regarding emergency lighting in the MR Examination room. There is no MR Safe DALI emergency lighting system which could be installed within the room. Agreed to check the Trust specification document to ensure compliance the system will be BS and Building Regulations compliant; to be reflected on the derogation schedule as necessary. Manual test will be provided in lieu of DALI self-checking system
    - RF cabin test dates to be advised with a few days' notice, expected next week.
    - Finishes samples selected on site and reflected on the latest architectural drawings included the 20mT flooring demarcation instructed.
    - Copies of site safety audit reports requested.
- Contractor's Report
    - Works currently on schedule for system delivery
    - Request for a Building Control application was clarified as being in respect of the cladding reinstatement, which was noted as being like-for-like with the existing. Application to be made
    - Penetrations to be properly stopped, including those through the floor slab. To be photographed and recorded.
    - Detail on who is providing fire stopping and fire dampers
    - Finishes sub-contractors to be appointed.
- Contractor's Queries and/or Requests for Information
    - Fire compartmentation and damper positions becoming crucial
- MRI Manufacturer
    - Scanner delivery RAMS to be issued
    - MR scanner is within the UK.
    - No BMS links being provided. Trust requirements to be checked.
    - Fire dampers will need to be connected to fire alarms

    - Access for drainage connections to adjacent rooms to be arranged with the department.
- Any Other Business
    - Complaint regarding exhaust position of welfare generator has been addressed by shielding/cowl.
- Access to fire/smoke dampers will be afforded from outside the MR Examination room.

Mid-January Progress Meeting 3

The third progress meeting wass held. Attendees included Project Manager, Head of Radiology, Trust Project Manager for Estates, MRI Lead Radiographers, representatives from Clinical Engineering, MRI Physics, MRI manufacturer, building contractors and the façade company

On the Agenda:

- Matters Arising from Previous Minutes
- Dates for cladding reinstatement confirmed
- Scanner delivery date confirmed. Survey date to be confirmed
- Scanner mains electrical cable installation (under Trust instruction) is pulled, awaiting connection and testing which is required most urgently to prevent delay.
- RF door (post Brexit) is being held in customs, to be released late January
- Revised scope of chilled water works is underway. RAMS to be issued for chiller delivery
- HTM derogation reports have been issued and circulated. Will chase sign-off.
- Electrical design review highlighted a request to replace the local power DB within the Control Room, this is included in the budget costs discussed
- Proposed injector installation date discussed
- Proposals in respect of emergency lighting within the Examination Room were further discussed since the last meeting and formalised within the derogations report.
- RF cabin test delayed due to RF door not being on-site
- MRI Physics acceptance dates - early March
- Site dilapidation inspection was undertaken on the date of the previous meeting. No significant issues were recorded although a minor repositioning of the chilled water pipework was assessed.
- Mechanical design drawings have been issued for comment and include previously instructed works. Updated drawings to be issued shortly to include additional fire damper works. No comments received in response to the designs, any further changes requested now will result in delays.
    - Survey of pipework in Control Room was undertaken and the pipes were confirmed as redundant, one has been removed one as the other is close to the wall and does not obstruct circulation. Fire-stopping to complete.
    - Copies of site safety audit reports requested.
    - Interpretation of existing fire compartmentation was issued for comment. Fire officer responded to request compartmentation of the MR suite, with acknowledgement the RF door and window are not fire rated installations. Feedback is awaited from Trust Fire Officer regarding the suitability of the existing Control Room doors, which appear to be fire doors.
    - Although scanner delivery date is due to be maintained, it was highlighted there will likely be fire stopping and ventilation works ongoing afterwards which may impact on clinical service
    - Fire-stopping will include floor penetrations.
    - All finishing trades now appointed.
    - Need to clarify any BMS expectations.

    - Check with mechanical installers any need to access adjacent areas to complete plumbing connections and coordinate with local staff accordingly.
- Contractor's Report
    - Works currently on schedule for system delivery
    - RF cabin installation has progressed well, except for the door delay
    - Out of hours works for chiller pipework are underway
    - Internal doors on site
    - Vinyl flooring works being rescheduled to better coordinate completion of RF cabin and ceiling, to allow for ductwork changes associated with fire dampers.
    - Delay due to fire protection works to be established.

    - Contractor's Queries and/or Requests for Information
    - As above
- Manufacturer
    - Trust confirmed no additional purchase orders have been raised against this project at present. To be monitored.
- Employer's Matters
    - Scanner delivery date confirmed
- CDM Regulations
    - No incidents to report
    - A number of complaints and warnings have been made regarding contractors parking around the site. Trust security will be issuing parking tickets
- Any Other Business
    - Next building works valuation being processed in the coming week

Late January

The RF cage was installed, and the RF test results issued. Outside (RF cabin) reference levels were taken, and the RF cabin was tested at frequencies of 15, 63 and 128 MHz at the scanner room door, control room window and penetration panel.

February

Early February -Progress Meeting 4

The 4th progress meeting was held. Attendees included Project Manager, Head of Radiology, Trust Project Manager for Estates, MRI Lead Radiographers, representatives from Clinical Engineering, MRI Physics, MRI manufacturer, building contractors and the façade company

On the Agenda:

- Matters Arising from Previous Minutes
- Dates for cladding reinstatement confirmed. Scaffold will not be present. RAMS to be checked and reissued
- Scanner delivery date confirmed. Manufacturer visiting site today to re-issue updated delivery RAMS
- Scanner mains electrical cable installation (under Trust instruction) has been connected and tested. Manufacturer needs test certificate for delivery.
- Medical gases works on track, pharmacist input being arranged
- RF door is fitted, test certificate to follow. Cage modifications being made to facilitate damper works, retest date to be confirmed

- Need building contractors feedback on Control Room door fire rating
- Chiller delivered, pipework and commissioning ongoing
- Injector installation date confirmed
- HTM derogation reports have been issued, signed off and deemed closed
- MRI Physics access confirmed and manufacturer programme has been circulated
- New H&S file to be issued at project completion
- Mechanical design drawings have been issued for comment and include all instructed works. No further Trust or Fire Officer comments received in response to the designs
- Survey of pipework in Control Room was undertaken and the pipes were confirmed as redundant. Fire stopping to penetrations, walls and works to fire dampers/ductwork underway
- Copies of site safety audit reports issued
    - Fire compartmentation works are underway. One damper is above the RF cabin, so an access hatch has been formed. Access will not be possible once scanner is ramped to field,
    - Mechanical installers have been working evenings to minimise any impact on department. No issues to report
    - Valuation due shortly, any splits between additional purchase orders to be advised
- Contractor's Report
    - Works have been focussed on preparation for damper installations following the last meeting
    - RF cabin ceiling to be completed once ductwork is fitted
    - Cable containment being completed later this week following RF cabin ceiling
    - Chiller being commissioned this week
    - Pre-delivery inspection date/time confirmed
    - Access to decorate Control Room being managed locally
    - Site hoardings and temporary screens working well in shared control room
    - Instruction given to provide new vinyl flooring to the Control Room
    - MR lead radiographer to confirm changes to Control Room furniture

    - Contractor's Queries and/or Requests for Information
    - Nothing further to report.
- Manufacturer
    - Magnet is in storage, collection date confirmed
- Employer's Matters
    - Site inspections to be made prior to closing ceilings
    - Damper demonstrations to be provided
    - Scanner delivery date confirmed
    - CDM Regulations
    - No incidents to report
- Any Other Business
    - None to report

Mid –February

Pre and post MR scanner delivery RF cabin attenuation tests and RF cabin installation and completion report issued. Outside (RF cabin) reference levels were taken, and the RF cabin was tested at frequencies of 15, 63 and 128 MHz at the scanner room door, control room window and penetration panel. All attenuation measurements were within the manufacturer specifications.

Early March - MRI Physics Commissioning/Acceptance Testing

With installation complete commissioning /acceptance testing was performed by the MRI Physics team. An overlap with the installation engineer is always useful to receive copies of their test results (magnet shim, manufacturer quality assurance (QA) checks, coil (QA), test tools report, tune up) and general manufacturer scanner information for future reference.

MRI Physics Tests/Safety Checks

The following general safety checks and measurements were performed:

- **Fringe field measurements** were recorded at various locations using a 3-Axis Hall Magnetometer to ensure appropriate control of access to restrict public entry to areas above the B0 Hazard threshold.
- **Acoustic Noise Levels** were measured using a digital sound meter particularly when running sequences with rapid gradient switching and compared to exposure limits specified in the Control of Noise at Work Regulations 2005
- Display of appropriate **MR Safety Notices** was checked at the entrances to the RF cabin, the technical room, control room, and for the emergency electrical stop, quench button, and oxygen monitor
- **Quench ventilation** exit point checks to ensure that the cryogen hazard zone would be clear in the event of a quench, suitable MR Safety notices were displayed and access was restricted at the exit point to limit entry to the cryogen hazard zone.
- **Ancillary Equipment** was labelled appropriately
- **Fire extinguishers** within the MR Suite were non-ferromagnetic and appropriately labelled
- **Functionality** of the patient intercom, emergency lamp, couch stop, couch release, bore ventilation, bore CCTV and emergency room ventilation fan.
- **The Inventory** was checked against purchase order and the serial numbers of installed coils recorded.
- **Manufacturer's QA tests** results were within specification including: coil QA, RF spikes, shim, eddy current compensation.

Medical Physics acceptance testing was performed but is outside the scope of this document.

What went well?

- There was good communication throughout the installation between the project management and the hospital team**.**
- The project team included a wide range of staff groups including external project manager, Radiology, Estates, MRI Lead Radiographers, Clinical Engineering, MRI Physics, PACS team, MRI manufacturer, building contractors and the façade company
- The project manager was very experienced and organised, meeting minutes were sent out promptly, and there was a good level of engagement with all relevant parties involved
- Ceiling pressure relief panel installations did away with the need and considerable cost of a scanner room door hatch

What did not go so well?

- Since the original MR scanner had been installed there had been a lot of building alterations(internal and external) so the original removal/delivery route was out of the question.

- A relatively new façade had been fitted to the front of the hospital which needed to be removed to allow removal of previous/installation of replacement MR scanner at considerable increased the cost to the project (approx. 70k).
- The door to the MR Examination room needed to open inwards (not recommended) as the vaulted ceiling soffit outside the scanner room fitted post original MRI installation now obstructed a door opening outwards.

8.2 Example 2

This Fly on the Wall account was for an installation which was intended to be a new build (new MRI and CT scanner) housed in an extension to a community hospital. This was complicated by the fact that the community hospital was a listed building and there were tight regulations/specifications for extending the building which weren't compatible with what would make a functioning MR/CT unit. The new MR/CT units were eventually installed in a relocatable POD while the planning for the extension to the listed building continued.

This is an example where Medical Physics weren't directly involved with the project and were not invited to attend meetings. There appeared to be a lack of communication between the project management, manufacturer, Trust MR Lead, MR radiographers and MRI Physics leading to a MR relocatable unit which wasn't as ideal as it could have been.

Timelines were as follows:

November

Initial plans to replace the current mobile MR scanner with a purpose-built MRI/CT was forwarded to MRI Physics for comment.

November - November of following year

Many issues followed with the design and planning permission for the new build as the hospital concerned was a listed building.

December

Initial designs for permanent building were shared with MRI Physics. Trust MR Lead requested information on any national guidelines and supporting documentation about proposed plans for the design.

December -November of following year

A decision was made to house the MR and CT in a temporary structure while planning permission and issues over the extension to the listed building (current community hospital) were resolved.

November

- Two possible locations for the relocatable MR scanner were sent to for MRI Physics for review, particularly with reference to the position of high voltage cables from an electrical substation at the back of the preferred carpark.
- E-mails from the manufacturer to the Trust MR Lead outlined details of the on-site applications training , with the specifics of training to be finalised once the actual dates were released by project management.

December

- MRI Physics were sent the plans for the "temporary" structure which would house the MR scanner until it could be moved into its permanent location.

- The project manager and manufacturer had received concerns from the adjacent property (a care home) about noise from the scanner during operation while in its temporary structure.
- MRI Physics measured the noise outside another similar POD already installed at another local Trust to estimate potential noise pollution.

January

The project management team issued the foundation drawings for review and comment to Radiology Manager and Trust MR Lead. There were recommendations for a trial pit to confirm ground conditions which required management of disruption to existing car park and list of key issues that needed clarifying:

1. Scope – exactly who is doing what, what pre-work do the Trust need to complete before the install occurs.
2. Logistics – Site set up areas, crane lift areas and lift plans, sequence, etc.
3. H&S – Method statements – what do the Trust need to see, who is the principal installation contractor, & is there one or more than one, etc)?
4. Programme – we need to firm up the attached.

Mid-January

The Trust MR Lead sent round questions following a project meeting (which didn't involve MRI Physics) about additional fixtures, quotes for injectors, MR Conditional equipment (e.g. trolley/chair), MR Conditional fire extinguisher. Queries were raised over scanner noise for the POD. Dates for applications specialist training were still to be arranged.

MR radiographer's questions/comments:

1. No need for an MR Conditional trolley, but a MR Conditional wheelchair, whilst not essential, would most definitely aid with flow and ensure a swift turnover between patients.
2. Assume that there is sufficient space to manoeuvre a patient on a trolley, from the reception area, past the toilet doors, and turning 90 degrees to enter the MR prep area?
3. Coil cupboard is desirable
4. A wall mounted pump loading system, outside of the scan room will aid flow.
5. Lockable drugs cabinet required.
6. A crash trolley shared with CT in reception area
7. Patient hoist available?
8. Sluice/macerator shared with CT?
9. PC and Landline essential

February

Exploratory excavations were planned at the site of the permanent extension (with a JCB) which was near to the current location of a mobile MR scanner. MRI Physics were concerned about level of vibration and recommend avoiding scanning on the day the closest hole was being dug.

Early March

The applications specialist e-mailed the Trust MR Lead with potential dates of mid Aprilfor applications training however there was no access to the scanner for clinical MRI scans before the end of April due to on-going building work to install a reception pod with walkways and in the adjacent CT scanner.

Mid March

Revised schedule for the installation was issued with suggested dates for Medical Physics acceptance testing for early April. No Physics involvement in project meetings.

Early April

- MRI Physics e-mailed the project management team about the expected schedule for the MRI installation as the Physics acceptance was originally planned for that week but there had been no confirmation this was going ahead.
- MRI Physics were informed that manufacturer commissioning had been completed and the MR scanner was ready for acceptance testing , but an engineer was needed on site as they had the keys to the unit.
- More e-mail correspondence followed with project management stating that reception hasn't been finished and wasn't ready for patients so MRI Physics couldn't do the acceptance testing There would be an issue getting engineers on site to give MRI Physics access, so Physics acceptance was booked for mid-April once we explained that no patients were being scanned during acceptance testing.

The acceptance testing went smoothly on the day, the images analysed, and acceptance report generated. The MR Local Rules were updated to include the replacement scanner.

MRI Physics requested the following:

- A copy of the cage certificate
- Information on what ventilation measures were in place in case of a Helium leak inside the scanner room as there didn't appear to be an emergency extraction system hooked into the O2 monitor
- Information on handover arrangements
- Dates for applications specialist training r as MRIPhysics wanted to attend.

What went well?

- Despite MRI Physics not being invited to project meetings or cc'd in emails there was good communication between the MRI Radiology/MRI radiographer teams to ensure MRI Physics were informed and involved
- Acceptance testing went smoothly

What did not go so well?

- Project meetings didn't include all staff groups as recommended in the MHRA guidelines to facilitate a smooth installation
- There was poor communication between project management, MRI physics, MRI radiographers and Radiology/Imaging throughout the project.
- Major issues with plans for MR/CT in extension to existing location as this was a listed building with strict building regulations. Had to plan for move to temporary POD instead
- Unforeseen potential vibration issues for the POD which required investigating
- Unforeseen noise pollution measurements due to POD location next to Care Home.
- Retrospective design issues included:
    - No room for a trolley in the MR POD apart from in theMR Examination room

- Poor patient evacuation route, with the need to open a gate to get a trolley out into a car park
- Use of semi-private changing area as preparation/cannulation room for patients requiring contrast so only 1 patient in at a time despite having 2 cubicles, s
- No sink in the changing/preparation area, so staff need to walk past staff in the control room to use the sink for hand washing
- No room around the sink for mounting soap dispensers/towels, these were located on a wall to the side
- The Fire panel was located in the technical room and would have been better in the control room for accessibility
- Two RF doors into the MR Examination room; the one from technical room was unnecessary as there was external access to the technical room

- MRI Physics acceptance testing scheduling issues included:
  - Lack of communication over acceptance testing dates
  - Access to MRI POD required an engineer to come on site
  - Confusion from project team over acceptance testing involving patient scans

9 References

ACR manual on MR Safety (2024), https://www.acr.org/Clinical-Resources/Radiology-Safety/MR-Safety

Anwar et al (2022) Paediatric magnetic resonance imaging adaptations without the use of sedation or anaesthesia: A narrative review. J Med Imaging Radiat Sci;53(3):505-514. doi: 10.1016/j.jmir.2022.04.048. Epub 2022 May 16.

BBC (2025) "Hospital says toy MR scanner helps save £150k", https://www.bbc.co.uk/news/articles/c24rlyprqq4o

BIR Risk Assessments, https://www.bir.org.uk/get-involved/special-interest-groups/bir-magnetic-resonance/mr-safety-risk-assessments.aspx

BS 5266-1 (2025) Emergency lighting - Emergency lighting of premises. Code of practice

Carter et al (2010) Mock MRI: reducing the need for anaesthesia in children. Pediatr Radiol. 40(8):1368-74. doi: 10.1007/s00247-010-1554-5. Epub 2010 Feb 26.

CIBSE (2019) LG02 Lighting for healthcare premises, https://www.cibse.org/knowledge-research/knowledge-portal/lighting-guide-02-lighting-for-healthcare-premises-2019/

CEMFAW (2016), The Control of Electromagnetic Fields at Work Regulations, https://www.legislation.gov.uk/uksi/2016/588/contents/made

College of Radiographers & Royal College of Radiologists (2024) Quality Standard for Imaging. https://www.collegeofradiographers.ac.uk/about-the-college/qsi

Heales and Lloyd (2022) Play simulation for children in magnetic resonance imaging. J Med Imaging Radiat Sci ;53(1):10-16. doi: 10.1016/j.jmir.2021.10.003. Epub 2021 Nov 24.

Health Building Note 00-01. General design guidance for healthcare buildings. NHS England (2014). https://www.england.nhs.uk/publication/designing-health-and-community-care-buildings-hbn-00-01/

Health Building Note 06-01. Facilities for diagnostic imaging and interventional radiology. In preparation

Health Technical Memorandum 00: Policies and principles of healthcare engineering. NHS England (2014). https://www.england.nhs.uk/publication/building-engineering-in-the-health-sector-htm-00/

Health Technical Memorandum 03-01: Specialised ventilation for healthcare premises. NHS England (2021). https://www.england.nhs.uk/publication/specialised-ventilation-for-healthcare-buildings/

Health Technical Memorandum 06-01: Electrical services supply and distribution. NHS England (2017) https://www.england.nhs.uk/publication/electrical-services-supply-and-distribution-htm-06-01/

Health Technical Memorandum 08-01: Acoustics. NHS England (2013) https://www.england.nhs.uk/publication/health-sector-buildings-acoustic-design-requirements-htm-08-01/

IEC 60601-2-33:2022 Medical electrical equipment - Part 2-33: Particular requirements for the basic safety and essential performance of magnetic resonance equipment for medical diagnosis. Reproduced as BS EN ISO 60601-2-33:2024

IPEM MR Safety signage (2017), https://www.ipem.ac.uk/resources/mri/mri-safety-notices-magnetic-resonance-imaging/

IPEM Report 112: Quality Control and Artefacts in MRI. IPEM (2017a)

MHRA Safety guidelines for MRI equipment in clinical use (2021). https://www.gov.uk/government/publications/safety-guidelines-for-magnetic-resonance-imaging-equipment-in-clinical-use

MHRA Managing medical devices (2021a). https://www.gov.uk/government/publications/managing-medical-devices

Moelker A et al (2003). Efficacy of passive acoustic screening: implications for the design of imager and MR-suite. JMRI Feb;17(2):270-5. doi: 10.1002/jmri.10251.

Mullally S (2013) A toolkit for medical equipment donations to low-resource settings: making It work. Global Health Partnerships. https://www.globalhealthpartnerships.org/resources/making-work-toolkit-medical-equipment-donations/

NHS England (2023) Processes for managing and reporting derogations from estates technical standards and guidance. https://www.england.nhs.uk/publication/processes-for-managing-and-reporting-derogations-from-estates-technical-standards-and-guidance/

NHS Supply chain (2025) https://www.supplychain.nhs.uk/product-information/contract-launch-brief/magnetic-resonance-imaging-scanners-and-associated-option-and-related-services/?utm_source=magnetic-resonance-imaging-scanners-and-associated-option-and-related-services

Recht P et al (2019), Optimization of MRI Turnaround Times Through the Use of Dockable Tables and Innovative Architectural Design Strategies. AJR Am J Roentgenol. Apr;212(4):855-858. doi: 10.2214/AJR.18.20459

Patients Association (2024), https://www.patients-association.org.uk/blog/how-can-patient-experience-of-diagnostic-services-be-improved

PSSR (2000), https://www.legislation.gov.uk/uksi/2000/128/contents/made

Quality Standard for Imaging (2024), https://www.rcr.ac.uk/our-services/management-service-delivery/quality-standard-for-imaging-qsi/

RIBA (2020) Plan of work. https://www.architecture.com/knowledge-and-resources/resources-landing-page/riba-plan-of-work

Small et al (2026) MRI faraday cage performance during the lifetime of clinical MR systems. MAGMA doi: 10.1007/s10334-025-01321-8

Society of Radiographers & British Associated of Magnetic Resonance Radiographers (2019) Safety in Magnetic Resonance. https://www.sor.org/learning-advice/professional-body-guidance-and-publications/documents-and-publications/policy-guidance-document-library/safety-in-magnetic-resonance-imaging

Society of Radiographers. Various guidance associated with MRI, https://www.sor.org/Learning-advice/Professional-body-guidance-and-publications/Documents-and-publications/Policy-Guidance-Document-Library?searchTerm=mri

Steckner et al (2024) Transitioning from 0.5 to 0.9 mT: Protecting against inadvertent activation of magnet mode in active implants. Magn Reson Med. 2024 Nov;92(5):2237-2245. doi: 10.1002/mrm.30153. Epub 2024 Jul 5.

Steckner et al (2026) Commentary: The MR scanner room door is a latent safety issue. MAGMA. doi: 10.1007/s10334-025-01310-x

Stunden et al (2021) Comparing a Virtual Reality-Based Simulation App (VR-MRI) With a Standard Preparatory Manual and Child Life Program for Improving Success and Reducing Anxiety During Pediatric Medical Imaging: Randomized Clinical Trial. J Med Internet Res 23(9):e22942. doi: 10.2196/22942.

UK Health Security Agency (2024) National coding taxonomy for incident learning in clinical imaging, MRI and nuclear medicine. https://www.gov.uk/government/publications/national-coding-taxonomy-for-incident-learning-in-clinical-imaging-mri-and-nuclear-medicine

Wilson et al (2019) Guidelines for the safe provision of anaesthesia in magnetic resonance units 2019: Guidelines from the Association of Anaesthetists and the Neuro Anaesthesia and Critical Care Society of Great Britain and Ireland. Anaesthesia 74(5):638-650. doi: 10.1111/anae.14578.