MR Safety case study

SAFETY IN THE MR LINEAR ACCELERATOR DEPARTMENT

An MR Linac (MRL) combines an MR scanner with a linear accelerator (Linac) and presents exciting opportunities for personalised radiotherapy. Currently available MRL systems incorporate magnets with field strength ranging from 0.35–1.5T.

The MRL department requires both therapeutic and diagnostic radiographers, radiotherapy and MRI clinical scientists and engineering staff. Ensuring adequate competency across both modalities requires training that may be difficult to deliver in the MRL department alone.

There is a range of testing equipment and tools for servicing the Linac in the Machine Room which, because of the necessity of a bunker for radiation protection, may only be accessible through the Treatment Room (figure 1)

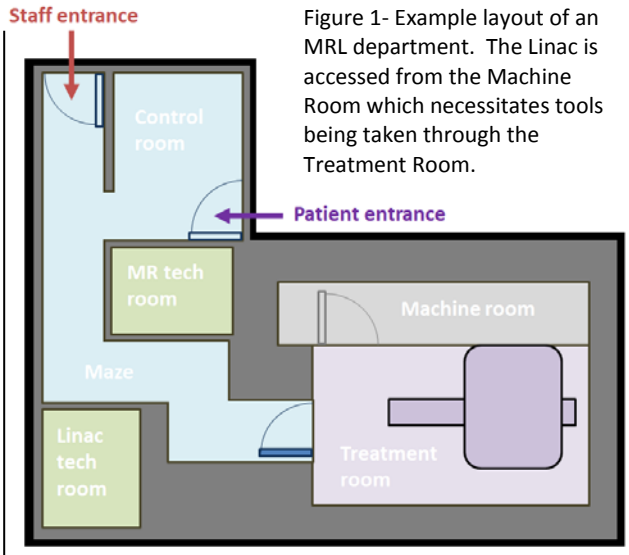

Figure 1- Example layout of an MRL department. The Linac is accessed from the Machine Room which necessitates tools being taken through the Treatment Room.

Addressing the challenges

Therapeutic radiographers and radiotherapy clinical scientists and engineers require extensive MR safety training to gain the knowledge and competence required to become MR Authorised Persons. The standard MR safety framework documentation based on MHRA guidance requires the following to be adapted:

- *Training of radiotherapy clinical scientists to an appropriate level so they can work without supervision while performing QA*
- *Systems of work to allow ferromagnetic tools to be safely taken through the Treatment Room and into the Machine Room by engineers (see Fig. 1). QA may also require detailed work instructions as 4D phantoms may contain ferromagnetic parts. Clear MR safety labelling is essential.*
- *MR training for therapeutic radiographers may require collaborative working with a diagnostic MR department.*
- *Adapting MHRA terminology and adding additional staff designations may be necessary (e.g. clinical and non-clinical MR Operators to allow radiotherapy clinical scientists to perform QA).*
- *Additional considerations for patients with active medical implants where both MR conditions and dose limits must be followed.*
- *Emergency procedures may require particular attention to planning and training. The hazards of the magnetic field and ionising radiation, specific patient requirements (e.g. mask) as well as the access maze must be considered when developing these plans.*

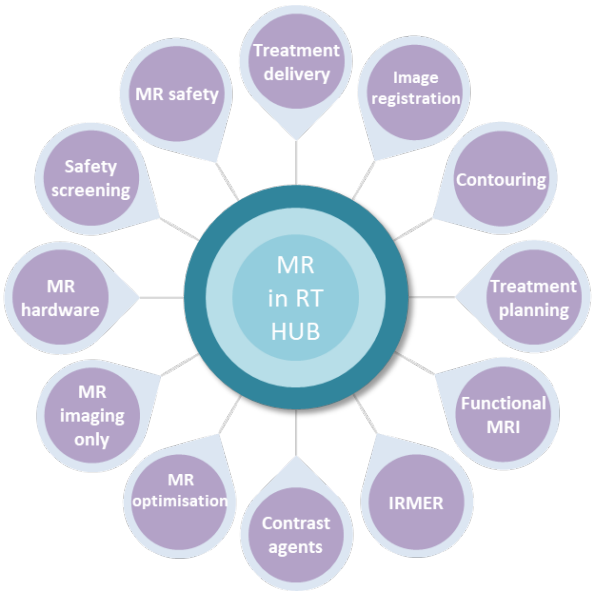

Figure 2 - Example hub-and-spoke education framework for the MRL department .

- *Development of a comprehensive MRL training programme to ensure appropriate knowledge and competency can be evidenced. This includes ionising radiation and radiotherapy training for MR staff groups. An example framework is shown in figure 2.*

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MR Safety case study

AN INCIDENT WITH MR UNSAFE EQUIPMENT

An MR Unsafe trolley was brought into the MR environment by a highly experienced MRI radiographer. This happened in the period between examinations when the room was otherwise empty. The error was noticed immediately, as the trolley was pulled towards the 3T magnet. The radiographer tried to hold back the trolley and got his hand trapped momentarily between couch and trolley, resulting in very minor injury

The MRI manufacturer was contacted to ramp down the field and remove the trolley – this happened the next day. All appointments for that day were cancelled.

The MR Safety Expert and the MR Responsible Person identified a number of factors that may have contributed to this error and considered many lines of action.

What was changed?

***Reduction of stress levels*:** The radiographer involved was under considerable pressure. A busy extended day was progressing with a challenging skills mix. MRI examinations were running late and junior staff members required help. The previous patient required an interpreter to be organised. **The way the translating services are managed within the MR controlled access area were changed.**

Labelling: The MR Unsafe trolley was appropriately labelled. However, the label could be hidden by items on top of the trolley. When in use, the attention is drawn to items on the trolley, and the trolley in itself is not the focus. **The labelling was changed and is now much larger, on all sides of the trolley.**

Trolley location: The MR Conditional trolley had been moved outside the MR environment and was not in its usual place - this may have contributed to this accident**. The probability of having accidents is smaller if the MR conditional trolley is always the first one to be found and always in the same place.** Aren't we all "creatures of habit" to some extent?

What was not changed?

More MR safety training: The MRI Radiographer in question is very knowledgeable – he has trained many others over years. This accident was not attributed to lack of knowledge or experience.

Replacing the trolley: The MR Conditional trolley and the MR Unsafe trolley are completely different in both design and colour. They would not usually be confused. The MR Unsafe trolley has necessary drawers. The MR Conditional trolley does not. If it had, additional precautions would be needed to avoid storing unsafe items.

Tethering of MR Unsafe trolley: The MR Unsafe trolley is used by the incident/outreach team and MRI Radiographers outside of the magnet room and it needs to move freely.

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ANAESTHESIA, SEDATION AND NEED FOR VIGILANCE

A child with scoliosis was referred for an MRI investigation of their spine. Due to their age, the patient was sedated with intravenous anaesthesia.

The monitoring equipment and anaesthetic machine were MR Conditional, and placed correctly inside the MR environment during the examination. The infusion pump delivering the anaesthesia was MR Unsafe, so was positioned in the MR control room and connected to the patient via a line passed through the waveguide. Induction was performed in the recovery area adjacent to the MR environment using a separate MR Unsafe anaesthetic machine and infusion pump. This is routine practice as it allows the anaesthetist(s) to closely monitor the patient in a safer clinical area than the MR environment during the induction process.

The patient's back brace, which contained some metallic bolts and buckles, had not been noticed prior to entering the MR environment. It was discovered when the localiser sequence showed a substantial susceptibility artefact (Figure 1). The radiographer immediately entered the MR environment and moved the patient out of the bore to check what was causing the artefact, discovering the back brace.

While removing the brace, the radiographer inadvertently knocked and broke the connection between the infusion pump and the patient. Scanning was resumed, but it was noticed shortly after that the patient was beginning to wake and start moving, requiring the anaesthetic team to quickly enter the MR environment and remedy the situation.

Why is it important?

MRI procedures that involve anaesthesia present additional MR safety concerns due to the increased presence of staff members who may be less familiar with the MR environment and an increase in the use of MR Conditional or MR Unsafe equipment.

Working practices should always be performed according to the guidelines published by the MHRA[1] and the Association of Anaesthetists and the Neuro Anaesthesia and Critical Care Society of Great Britain and Ireland[2]. A report into a separate tragic accident involving a child who died after an MRI under general anaesthetic has recently been published by the Healthcare Safety Investigation Branch (HSIB)[3]

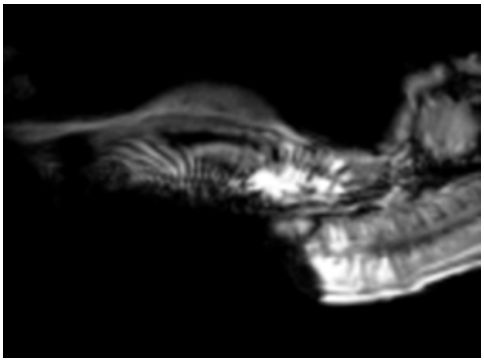

Figure 1. Localiser image of the sedated patient, showing the substantial image artefact caused by the metallic bolts and buckles in the patient's back brace.

How has this made a difference and what has changed?

The MR unit has since improved the level of MR safety training that can be accessed by members of the anaesthetic teams and introduced a final 'pause and check' procedure before any sedated patient enters the MR environment.

References

[1] Medicines and Healthcare products Regulatory Agency. Safety Guidelines for Magnetic Resonance Imaging Equipment in Clinical Use. 2016

[2] S.R. Wilson et al. Guidelines for the safe provision of anaesthesia in magnetic resonance units. Anaesthesia 2019 74(5): 638-650

[3] Healthcare Safety Investigation Branch. Undiagnosed cardiomyopathy in a young person with autism, 2020

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IMPROVING MR SAFETY FOR NEUROMODULATION

Neuromodulation as a treatment for pain syndromes, epilepsy, movement disorders and more has become more widespread over the last decade. Development includes new classes of device (figure 1) and treatment, MR safety enhancements and advances in the methods for assessing MR safety. The result is a wide variety of devices, with differing susceptibilities to the MR Environment. Patients may also have an increased need for diagnostic MRI, e.g. patients with chronic pain due to spinal disease may require additional spinal MRI to monitor disease progression or complications. It is important not to deny access to MRI for any clinically relevant indication (related or not to the past medical history) where it can be performed practically and safely.
Patients and referrers may have an incomplete understanding of MR safety, and it is important to communicate reasons for not scanning or reduced availability of diagnostic information.

Involving the clinical team

- Patients and implanting clinicians benefit from an understanding of any limitations to MR access
- The clinical team is a key point of access when determining device information and configuration (e.g. implant location, accessories) when protocolling an examination
- Device manufacturers can provide technical support as well as information on new products before they are implanted. They can also alert the department to changes in conditions.

A standard operating procedure

Due to the variety of devices, no single protocol is acceptable. Instead, the key is to robustly identify a device and its associated conditions, and provide clear instructions on how to meet those conditions. The development of such a procedure requires involvement of an MRSE or other person knowledgeable on MR safety. A core team should vet and perform these examinations. The following describes a procedure used at the author's institution.

Booking: Booking staff identify the presence of a device from the request, RIS alert or through patient contact. If a device is present, the clinical team are contacted and asked to return full details via a standard pro forma. If a device test or aftercare is needed, then a neuromodulation clinic appointment is booked to coincide.

Protocolling: A radiologist protocols the examination with reference to the manufacturer's documentation or for the most commonly seen devices, an in-house (regularly updated) device specific protocol form, and selects a protocol which meets the conditions.

Examination: The radiographer follows a device specific checklist, which provides a point-by-point procedure for the device which includes patient preparation and positioning; technical parameters e.g. B0, SAR, dB/dT, dB/dx; and aftercare. Scanners are pre-programmed with sequences tested for specific MR conditions (e.g. $B1_+$rms limits, local Tx/Rx coils), avoiding the need for ad hoc parameter changes.

A pain physician wished to start using a new peripheral nerve stimulation device, which boasted conditions permitting full body MRI at 1.5T and 3T. He approached the MRI department for clarification.

The manufacturer provided the conditions, which were complex with exclusions and severe limitations when scanning near the stimulator. The conditions were severely limiting at 1.5T and unachievable at 3T.

The physician was able to use this information to inform treatment options and obtain informed consent.

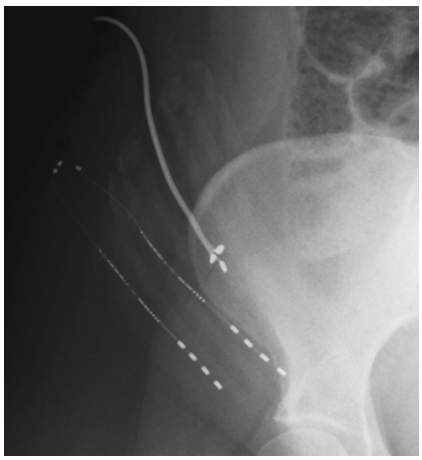

Figure 1 – Peripheral nerve stimulators have often not included MR conditions for scanning near the device. Newer devices (such as that shown) may correct this omission, but the conditions can be complex.

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