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Risk Management in MRI

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Risk management in MRI is, like the imaging technique itself, a multilayered problem. If we take into account an MRI superconducting magnet (the majority of installed equipment), four components of the device may cause a risk to the patient, staff, or both: the magnet (main magnetic field), the cryostat (liquid helium), the magnetic field gradients (low-frequency electromagnetic field, acoustic noise) and, finally, the transmit RF coil (radio frequency pulses).

Risks Related to the static Magnetic Field

The principle of magnetic resonance imaging requires the use of an intense magnetic field. Most commonly installed imaging devices include a 1.5 Tesla magnet, which is about 30,000 times the earth's magnetic field! Consequently, when a ferromagnetic metal object enters the magnetic field, it undergoes a violent attraction and its speed can reach several metres per second. This is called the missile (or projectile) effect of metal objects.

This is certainly the major risk related to MRI installation and relates to both patients and staff. Small objects such as scissors or a reflex hammer, for example, can pose a real threat if they reach a patient lying in the MRI bore. But the accident can be even more dramatic when large masses of metal, unstoppable near a strong magnetic field, are involved. In 2001, in the United States, a six year old child died as a result of head trauma caused by the projection of an oxygen cylinder in the magnet during the MRI examination. Personnel are exposed to the same dangers: being in the path of a small metal object or becoming stuck against the magnet by a large mass of metal (stretcher, bed, etc.).

The second risk relates to metal implants and implantable medical devices or metallic foreign bodies. In this case, the threat comes with displacements or rotations of these implants or foreign bodies resulting in sometimes dramatic, haemorrhage (ferromagnetic intracranial aneurysm clips, intraocular metallic foreign bodies, bullets or shrapnel, etc.) or the malfunction of certain implanted devices (pacemakers, nerve stimulators, cochlear implants, insulin pumps, etc.).

Prevention of these risks has several components:

Prevention and control by restricting access:

Access to the examination room should be limited to those aware of the constraints of magnetic fields. The danger is always evidenced by panels located on the door of the examination room or surrounding rooms. The limit of the magnetic field of 0.5 milliTesla (mT) is considered a prohibited zone to people with certain active devices (e.g. pacemaker), ferromagnetic objects and certain electronic equipment. This limit is generally contained in the magnet room through the advances in shielding: active shields at the magnet (additional magnetic field coils) and passive shielding attached to the walls, floor or ceiling if necessary (metal plates). If this is not the case (very high magnetic fields), the limit must be marked on the ground.

Access is normally controlled by radiologic technologists. It is just as important for staff (paramedical, medical, maintenance personnel etc.) as it is for patients. Any person entering the examination room must be removed of any ferromagnetic metal object, especially in pockets. Radiologic technologists must verify that those entering the room are not wearing a medical device prohibited in the area of 0.5 mT and all damageable goods (watches, credit cards, mobile phone, etc.) must be set aside. A metal detection gate at the entrance of the room can be useful for additional safety. For patients, it is advisable to completely undress them and ask them to wear a hospital gown without metallic buttons. They also need to remove jewellery, dentures and anything else that could be detrimental to the quality of the exploration (artefacts). A thorough

search of the contraindications, by a verbal interview or by a printed safety screening form, is a prerequisite.

For implanted material, a compatibility check with the manufacturer is often necessary. Some devices normally prohibited (e.g. pacemakers) can evolve to a possible use in MRI but with significant constraints for both staff and patients. In case of doubt about the presence of an implant, an active implantable medical device or metallic foreign bodies, the region of interest can be radiographed. Finally, for those accompanying patients in the exam room (which is common in paediatric MRI), they should take the same precautions as staff.

Prevention by use of specific equipment:

Any material or object entering the examination room must be non-magnetic and clearly identified as such to avoid the risks associated with the missile effect. This includes stretchers, wheelchairs, infusion stand rods, bins, pedestal preparation, etc. If there is still uncertainty of the ferromagnetic character of a device or object, simply do a test on the object with a small magnet.

Risks of the cooling Agent

To achieve the superconducting properties of the coil which produces the magnetic field, the latter is placed in an insulating container (cryostat) containing liquid helium at a temperature of - 269°C. The risk of such an installation is sudden and accidental loss of superconductivity, making the magnet become resistive: this is called the ‘quench’. The heating of the coil then transforms the liquid helium into a very large amount of helium gas. Normally, this gas is discharged to the outside of the building through a pipe called a ‘quench pipe’. In case of malfunction of the system, the risks to staff and patients are essentially cold burns and asphyxiation, because the sudden evaporation of helium will displace oxygen from the ambient air and thus reduce concentration.

Prevention in this area is primarily to periodically check the existing installation for leaks or blockage of the quench pipe. In addition, training of staff in emergency procedures is also important. Indeed, in case of partial or total failure of the quench pipe, and therefore release of helium gas in the examination room, staff must first evacuate the patient and then start the ventilation extraction to expel the gas in the room. Finally, the quench can be provoked deliberately (by pressing the switch to stop the magnet) in case of an accident with the risk of the projection of metallic elements in the magnet, in case of injury or blockage of the patient or staff, but also in case of fire in the room. However, this procedure that brutally stops the magnetic field should only be used as a last resort.

Risks associated with magnetic field gradients

The magnetic field gradients are the cause of two effects for the patient:

Peripheral nerve stimulation

This is manifested by tingling or slight muscular tremors in certain regions of the body. This effect is a consequence of certain sequences (especially echo planar imaging or EPI) during which the gradients switch extremely fast, which leads to low frequency electromagnetic fields and can generate currents in tissues (where the nerve stimulation occurs).

The prevention of this phenomenon requires compliance with the procedures for installing the patient. It is particularly important to avoid contact with the hands, knees or feet because it leads to a closed conductive loop favouring the induction of an electric current in the nerve fibres (and hence stimulation). It must also be ensured that the patient carries no metal objects or conductive material promoting the induction of electric current. In general, the devices offer also power management of the gradients at two levels; the lower level reduces the risk of generating peripheral nerve stimulation. In all cases, the operator must remain attentive to the sensations felt by the patient so that he can stop the examination if necessary.

The acoustic noise

Characteristic of the operation of the gradient coils, this noise is caused by the vibration of the gradient coils as a result of the injection of electric current. The noise is proportional to the intensity of the electric current and magnetic field strength, resulting in a higher noise when the main magnetic field increases.

Again, prevention is primarily the correct care and management of the patient. Using earplugs or noise cancelling headphones (or both!) can, in general, reduce noise by around 30 to 35 dB. From a technological perspective, the manufacturers also offer different methods of noise reduction or hardware or software (sequences).

The risks associated with transmit RF coils

The application of radiofrequency pulses during the acquisition sequences, that is to say, high-frequency electromagnetic fields generated by the transmit coil, causes power transmission in the tissues, which can lead to overheating. This energy deposition is measured in SAR (Specific Absorption Rate) which is calculated in W / kg. International Standard IEC 60601-2-33 sets limits on power transmission to not exceed an increase in body temperature of 1°C. In practice, the SAR depends on the sequences parameters used, particularly the number of radio frequency pulses (e.g. in fast spin echo sequences) or also on the flip angle of the pulses.

The transmit coil may be the cause of another risk: in fact, the concentration of the radiofrequency field on the skin can cause second or third degree burns. This danger is enhanced by the presence of electrical cables forming a loop on the skin (receive coil cables, ECG cables, etc.), the contact between a metal conductor and the skin (e.g. skin patches containing a metal sheet or body piercings) and skin-to skin contact forming a conductor loop (for example on limbs or crossed arms).

Prevention of tissue heating is provided primarily by software equipping each device to continuously calculate the SAR according to the sequences parameters used. The operator is alerted in case of exceeding the threshold. As for nerve stimulation management, it also has two levels of use, the low level allowing less energy transmission. Another security measure is to clearly indicate the patient's weight because it contributes to the precise calculation of SAR. Also avoid switching to high power transmission with young children and patients with hyperthermia or those with alterations in thermoregulation. We must also be careful not to cover patients too much and ensure good ventilation of the magnet bore.

To avoid the risk of skin burns, do not let a receive coil cable come into contact with the patient's skin. The operator must also ensure that there is a minimum distance of 5mm between the patient and the sides of the magnet bore, confirm the absence of any conductive metal in contact with the skin and avoid skin-to-skin contact (risk of burns at certain contact points). As always, the operator must remain attentive to the patient (call button), asking him or her to report any abnormal sensation of heat.

Conclusion

MRI safety is an important issue, with risks for the patient and the staff. This is a daily concern for the operator, mostly the radiologic technologists, which should ensure the smooth running of the MRI examinations and the patients' safety.

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