



FOCUS ON
HEALTH

Radiography and Clinical Technology

Self-study CPD activity

Activity Reference Number:

A13(25)

Topic

MRI

Article(s)

Instrumentation and safety
Patient and Staff safety

Speciality

Diagnostic

Profession(s)

Radiographer
Radiologist

Part 1 of this activity is approved for **THREE (3) Clinical** Continuing Education Units (CEU's)
Part 2 of this activity is approved for **THREE (3) Clinical** Continuing Education Units (CEU's)
Part 3 of this activity is approved for **THREE (3) Clinical** Continuing Education Units (CEU's)
Part 4 of this activity is approved for **THREE (3) Clinical** Continuing Education Units (CEU's)

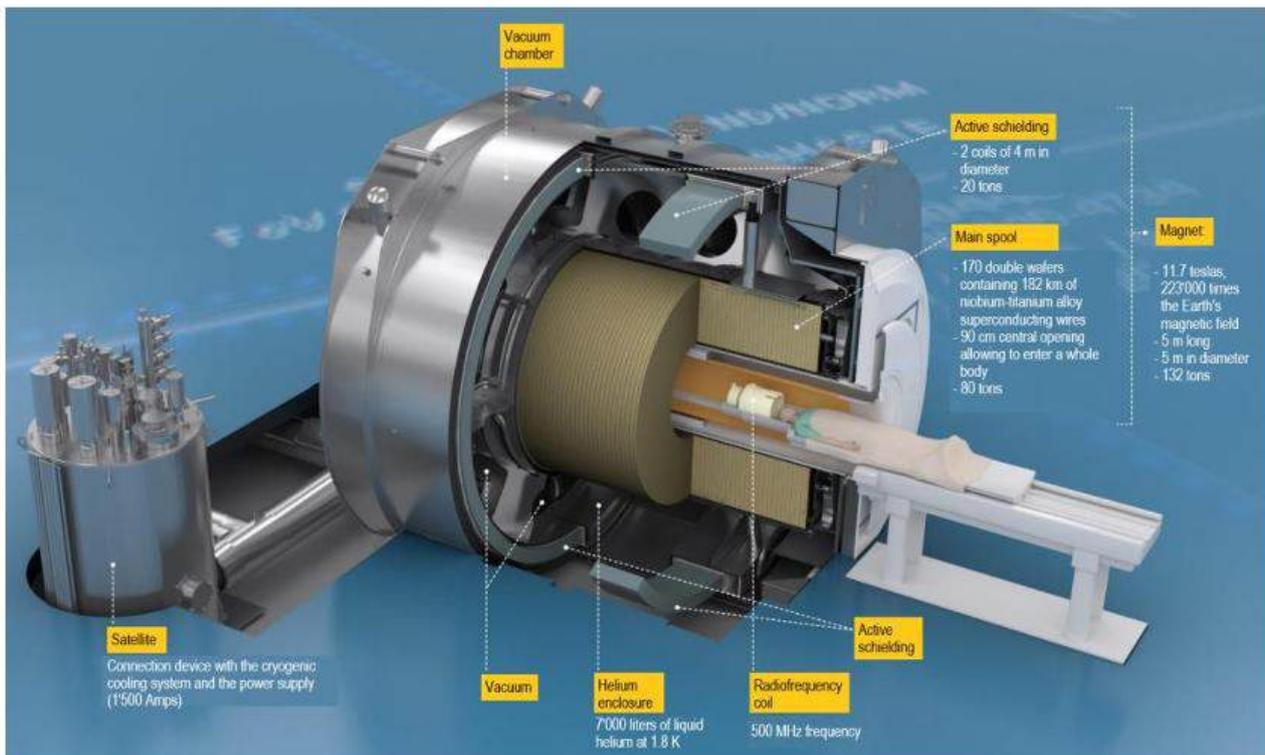
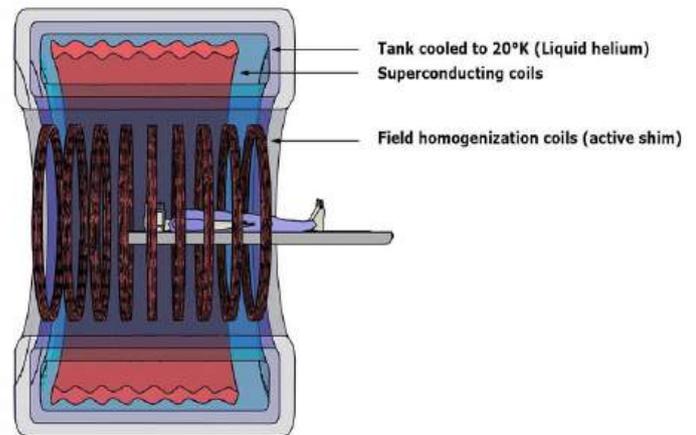
A13(25)

MRI

INSTRUMENTATION AND SAFETY

MRI MAIN MAGNET

- The main magnet creates the static magnetic field, forming the basis for measurable macroscopic magnetization
- Types of magnets
- The design of MRI is essentially determined by the type and format of the main magnet, i.e. closed, tunnel-type MRI or open MRI
- The most used magnets are superconducting electromagnets
- These consist of a coil that has been made superconductive by helium liquid cooling
- They produce strong, homogeneous magnetic fields, but are expensive and require regular upkeep (namely topping up the helium tank)



SUPERCONDUCTING MAGNETS

- In the event of loss of superconductivity, electrical energy is dissipated as heat.
- This heating causes a rapid boiling-off of the liquid helium which is transformed into a very high volume of gaseous helium (quench)
- To prevent thermal burns and asphyxia, superconducting magnets have safety systems: gas evacuation pipes, monitoring of the percentage of oxygen and temperature inside the MRI room, door opening outwards (overpressure inside the room)
- Superconducting magnets function continuously
- To limit magnet installation constraints, the device has a shielding system that is either passive (metallic) or active (an outer superconducting coil whose field opposes that of the inner coil) to reduce the stray field strength



Conventional superconducting scanner (left) containing ~1500 L of liquid helium compared to a Philips BlueSeal magnet containing only 7 L. (Courtesy Philips Medical Systems).

POSSIBLE ACCIDENTS HAPPENING IN AN MRI UNIT

- Magnet quenching
- Helium levels dropping very low

MAGNET QUENCHING

- Quenching is the process where there is a sudden loss of absolute zero of temperature in the magnet coils, so that they cease to be super-conducting and they become resistive
- This results in helium escaping from the cryogen bath extremely rapidly
- Quenching may happen accidentally or may be instigated manually in the case of an emergency

QUENCH BUTTONS



MAGNET QUENCHING

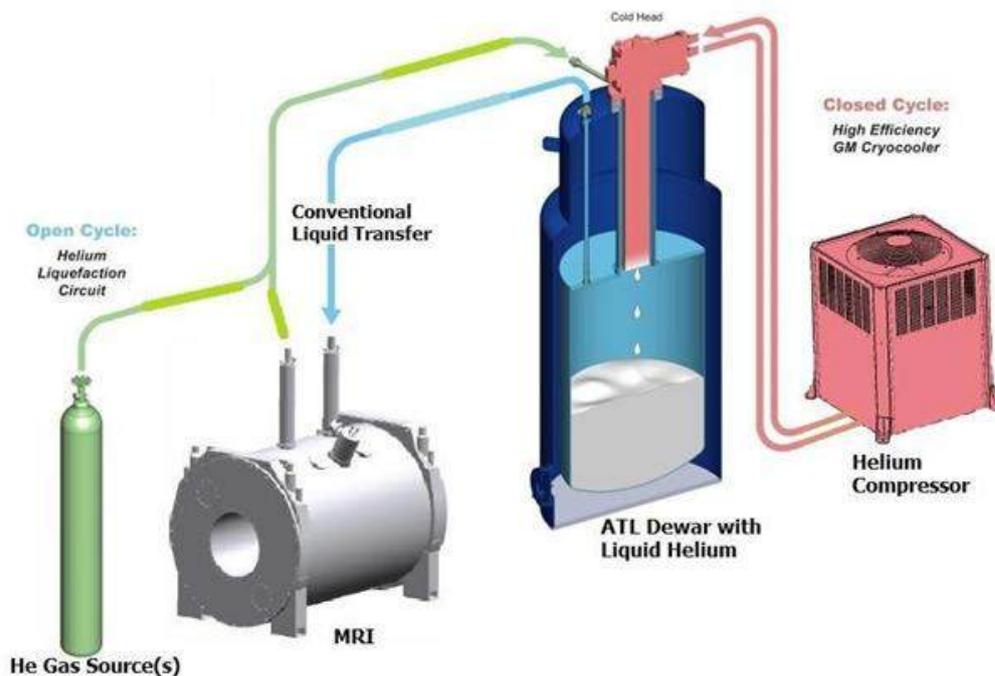
- Quenching of the magnet may cause severe and irreparable damage to the superconducting coils and therefore a manual quench should only be done if a person is pinned to the magnet by a large metal object that cannot be removed by hand
- All systems should have helium venting equipment which removes helium to the outside environment in the event of a quench
- However, if this fails, helium vents into the room and replaces oxygen
- For this reason, all scan rooms should contain an oxygen monitor that sounds an alarm if the oxygen level falls below a certain level

OXYGEN DEPLETION ALARM MONITOR



- Oxygen depletion monitors are used as safety alarms to give warning when the room oxygen levels reach 19.6% or below, which indicates unsafe air quality
- Particularly if the oxygen is slowly being replaced by helium

LIQUID HELIUM TANK AND COMPRESSOR



WHY DOES AN MRI MACHINE NEED LIQUID HELIUM?

- An MRI machine contains coils, a magnet and wires that conduct current
- The machine uses a great deal of energy because of its large magnetic field.
- In order for it to use that much energy, it must be super conductive
- For this to occur, wires inside the machine need to be reduced to a temperature of near zero degrees
- The machine requires a substance in order for it to maintain a cold temperature, and that substance is liquid helium
- The amount of helium in the scanner must be topped off on a regular basis which increases the amount of helium used by the machine even further
- In summary, liquid helium is used to cool down the superconductive magnets coil in MRI scanners to a temperature below 10 Kelvin

LOW FIELD MRI

- These are resistive electromagnets, which are cheaper and easier to maintain than superconducting magnets
- These are far less powerful, use more energy and require a cooling system
- Permanent magnets, of different formats, composed of ferromagnetic metallic components
- Although they have the advantage of being inexpensive and easy to maintain, they are very heavy and weak in intensity
- To obtain the most homogeneous magnetic field, the magnet must be finely tuned (“shimming”), either passively, using movable pieces of metal, or actively, using small electromagnetic coils distributed within the magnet

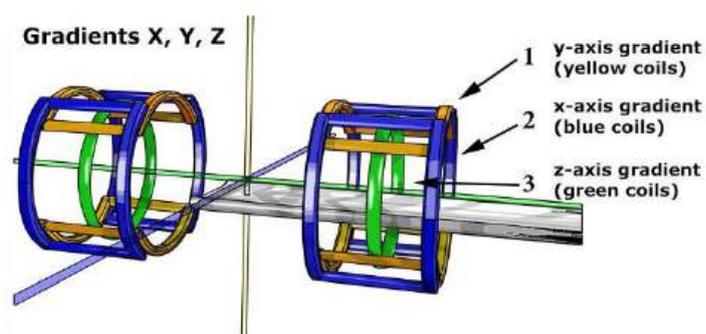
CHARACTERISTICS OF THE MAIN MAGNET

- The main characteristics of a magnet are:
- Type (superconducting or resistive electromagnets, permanent magnets)
- Strength of the field produced, measured in Tesla (T). In current clinical practice, this varies from 0.2 to 3.0 T
- In research, magnets with strengths of 7 T or even 11 T and over are used

MAGNETIC FIELD GRADIENTS

- Magnetic field gradients are needed to encode the signal spatially
- They produce a linear variation in magnetic field intensity in a direction in space
- This variation in magnetic field intensity is added to the main magnetic field, which is far more powerful
- The variation is produced by pairs of coils, placed in each spatial direction.

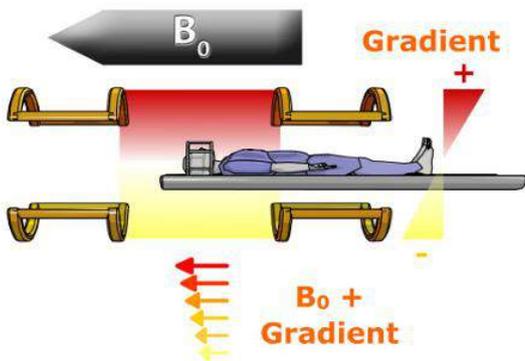
GRADIENTS COMPONENTS



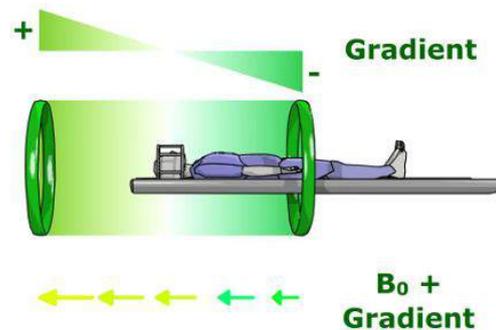
HOW GRADIENTS WORK

- The direction of the magnetic field is not modified
- By adding them to B_0 , a linear variation is produced in the total magnetic field amplitude, in the direction to which they are applied
- Their action is considered as homogeneous on a plane perpendicular to the direction of application
- This modifies resonance frequency, in proportion to the intensity of the magnetic field to which they are submitted (in accordance with Larmor's equation: the stronger the field, the faster they process)
- This variation in Larmor frequency also causes a variation and dispersion of spin phases

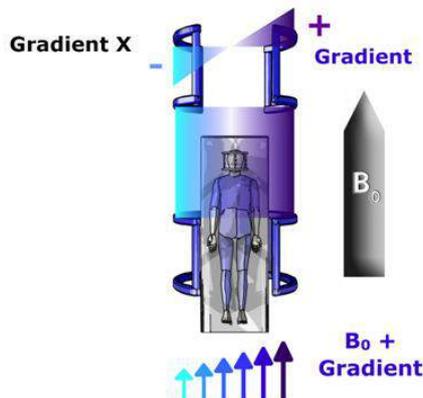
GRADIENTS



- Variations in the field produced by gradients in direction y



- Variations in the field produced by gradients in direction z



- Variations in the field produced by gradients in direction x

GRADIENT CHARACTERISTICS

Gradient performances are linked to:

- Their maximal amplitude (magnetic field variation in mT/m), which determines maximal spatial resolution (slice thickness and field of view)
- Their slew rate, corresponding to their switching speed: high slew rates and low-rise time are required to switch gradients quickly and allow ultra-fast imaging sequences such as echo planar (EPI)
- Their linearity, which must be as perfect as possible within the scanning area

EDDY CURRENTS

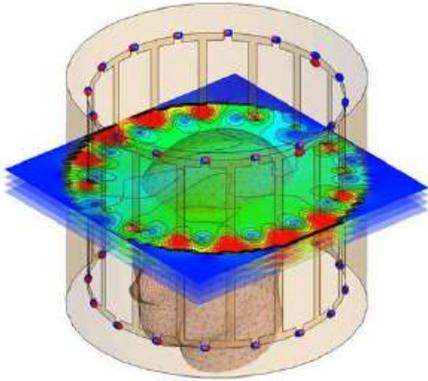
- The rapid switching of the gradients induces currents in the conducting materials in the vicinity of the gradient coils (cryogenic envelope, electric wires, antennas, homogenization coils, etc.)
- These induced currents (Eddy current) will oppose the gradient fields and cause a decay in their profile
- There are several methods to reduce the effects of these induced currents:
- Active gradient coil shielding
- Optimizing the electric current profile sent to the gradient coils while ascending and descending to offset the Eddy currents
- Moreover, gradient switches produce Lorentz forces causing vibrations in the gradient coils and their supports
- These vibrations are the main source of the characteristic MRI noise

RADIOFREQUENCY SYSTEM COMPONENTS

- The radiofrequency system includes all the components for transmitting and receiving the radiofrequency waves involved in exciting the nuclei, selecting slices, applying gradients and in signal acquisition
- Coils are a vital component in the performance of the radiofrequency system.
- In transmission, the goal is to deliver uniform excitation throughout the scanned volume
- On reception, the coils must be sensitive and have the best possible signal- to -noise ratio

RF COILS

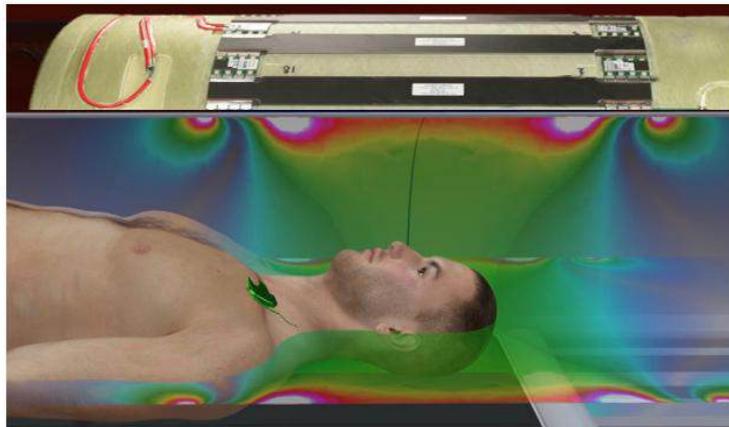
- To generate an MR signal, protons require external stimulation at energies near the resonance frequency
- This stimulation comes from an externally positioned radiofrequency (RF) transmit coil
- The most common RF-coil design for 3.0T is the birdcage coil, a cylindrical structure with multiple rungs
- Although local transmit RF-coils may be used for head, knee, and small-parts imaging, the bulk of RF transmission for MRI is performed by birdcage-style "body coils" located immediately beneath the plastic walls of the scanner



Magnetic fields generated by a head-only RF birdcage coil. Colored circles represent capacitors. (Courtesy of P. Fütter, computed with FEKO)

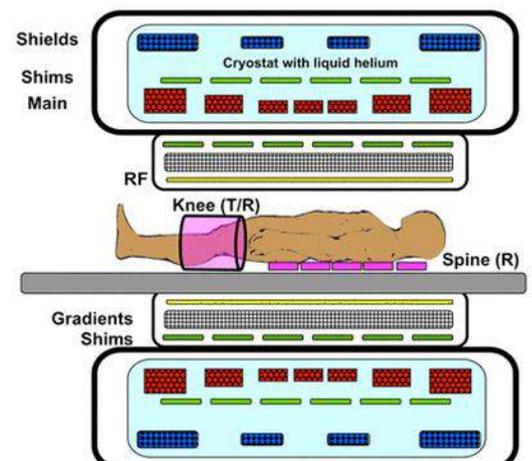
- Standard RF-transmit body coils are only about 50 cm in length and thus do not extend the entire length of the scanner bore (which may be up to 100 cm long)
- They are positioned to straddle magnet isocenter and produce strong, uniform excitation within this region
- Transmitted power dies out significantly as one moves away from isocenter

- The RF power can be as much as 3x stronger near the scanner walls in locations immediately adjacent to the coils
- Focal "hot spots" are present within a few centimeters of the junction of each birdcage rung
- These hot spots repeat around the periphery of the magnet bore according to the number of rungs (e.g. 16-32)
- A patient whose hand, shoulder, or other body part touches the scanner walls (or comes close in these hot spots) is at increased risk of a cutaneous burn
- Same applies to a wire or cable passing through the hot spots may be more likely to acquire an induced electric current

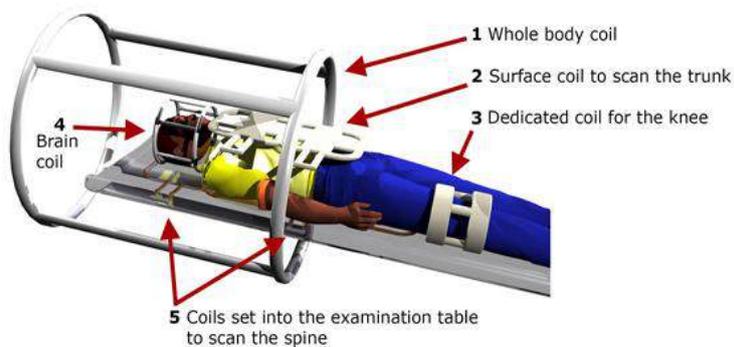


Distribution of peak B1 within the bore of a 3T MR scanner. Note the local RF "hot spots" adjacent to the ends of the RF-coil rungs. (Lower half of image courtesy of Dr. E. Kanal, created using the MagnetVision™ app he created)

- Representative cross-section of a superconducting scanner showing nested arrangement of "coils"
- Both superconducting and resistive shim coils are shown
- Two different types of patient coils are also illustrated: a receive only spine coil array, and a transmit/receive knee coil



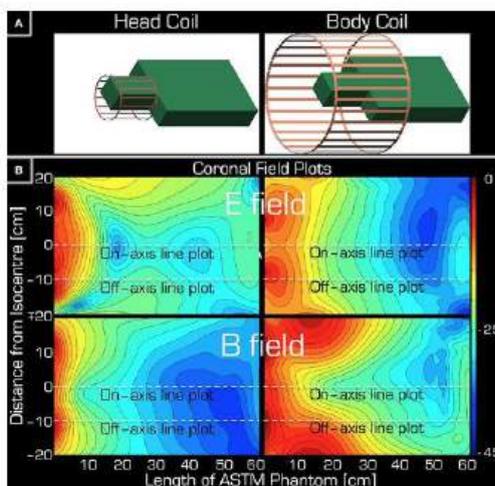
RADIOFREQUENCY SYSTEM



- An MR scanner generally contains a whole-body coil, located in the cylinder of the machine, uniformly covering the entire scan volume
- The sensitive volume of surface coils, being placed in direct contact with the zone of interest, has less depth and is more heterogeneous
- However, surface coils offer a better signal to noise ratio and imaging capacity with higher spatial resolution
- The homogeneity and sensitive volume of surface coils can be improved by combining them into a phased array
- They still have the advantage of a better signal to noise ratio, but at the cost of more complex signal processing

Main field (B_0) Coils (Principal magnet windings plus superconducting shim and shield coils)

- Shim Coils (to improve homogeneity)
- Gradient Coils (for imaging, including their active shields)
- Radiofrequency (RF) Body Coil (transmits B_1 field)
- Patient coils (primarily to detect MR signal, some are transmit/receive)



- Transmit-receive coils (e.g. for head and knee) have certain advantages over body transmit coils because their magnetic (B) and electric (E) fields are more confined and have less effect on non-imaged body parts
- This is illustrated in the field plots below calculated for a gel-filled ASTM phantom
- Of interest is that the E fields are maximal in the center of each rung whereas the B fields are concentrated at the ends

QUADRATURE RF COILS

- Quadrature RF coils (circularly polarized coils) consist of at least two coils that are oriented orthogonal to each other (and both are orthogonal to B_0 axis)
- They have a better signal-to-noise ratio than linear RF coils.
- Depending on the manufacturer and the type of coil, certain coils can be transmitters, receivers or both
- The radiofrequency channel also comprises analog-digital converters and a spectrometer to receive and analyze the signal

OPTIMIZING THE RADIOFREQUENCY CHANNEL

- Optimization of the radiofrequency channel is automated and carried out in several stages prior to an imaging sequence:
- The exact Larmor frequency is set, this being slightly modified by the patient's presence in the magnetic field
- Transmission power is adjusted according to the weight of the patient and the transmit coil, to obtain the desired flip angles
- The receiver gain is adjusted to avoid signal saturation or conversely, weak amplification resulting in a deteriorated signal-to-noise ratio

SPECIFIC ABSORPTION RATE (SAR)

ABSORBED DOSE

The specific absorption rate (SAR) describes the potential for heating of the patient's tissue due to the application of the RF energy necessary to produce the MR signal.

- This dose means the RF power absorbed per unit of mass of an object
- It is measured in watts per kilogram (W/kg)
- The absorbed dose is dependent on the duty cycle and transmitter-coil type and increases with field strength, radio frequency power and body size

ACOUSTIC NOISE

- Vibrations of the gradient coil support structure create sound waves
- These are caused by the interactions of the magnetic field created by the pulses of the current through the gradient coil with the main magnetic field in a manner similar to a loudspeaker coil
- The sounds made by the scanner vary in volume and tone with the type of procedure/sequence being performed
- MRI system noise increases with field strength

LEARNING POINTS ON RF COILS

- The dominant biological and safety effect of RF stimulation is tissue heating
- This can range from acute cutaneous burns to generalized increase in body temperature to localized heating around implants

FARADAY CAGE

- As the resonance frequency of protons is very close to that of the radio waves used in radio broadcasting and the FM band, the MR device is placed in a Faraday cage to insulate it from external RF signals which could alter the signal. The copper Faraday cage completely encases the MR scanner. Openings through this cage need to be carefully designed to avoid canceling out the shielding effect

SAFETY PRACTICES IN MRI

- There are different types of contraindications that would prevent a person from being examined with an MRI scanner
- MRI systems use strong magnetic field strength that attract any ferromagnetic objects with enormous force
- There is a potential risk of heating produced from the radio frequency pulses during the MRI procedure and for this reason, metallic objects like wires, foreign bodies and other implants need to be checked for compatibility
- In addition, any device or MRI equipment that enters the magnet room has to be MR safe

SOME MYTHS ABOUT MRI

- In recent years MRI safety has received increased media attention with growing public concern
- From controversies over the side-effects of gadolinium to projectile accidents, a serious MRI incident always makes news
- It is possible to practice completely without incident, as long as one can distinguish between the myths and maths of MRI safety

Let us look at some of the few myths around MRI safety:

- Myth: the various magnetic fields involved in MRI- the static field (B_0), switched gradients and radiofrequency (RF) - are different entities, to be treated differently when considering MR safety
- Maths: they are all magnetic fields. They display different spatial characteristics and frequencies, but they are all subject to the same physical laws of magnetization and induction. Only the relative strength of these two interactions vary

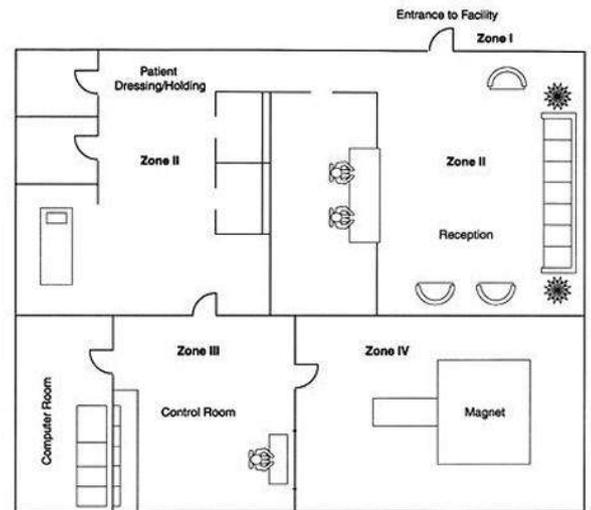
- Myth: the tesla is the SI unit of magnetic field strength
- Maths: the tesla is the SI unit of magnetic flux density. Magnetic field strength or intensity is measured in amperes per metre. We have been using the wrong terminology for decades!

- Myth: the translational force on a ferromagnetic object depends upon its magnetic susceptibility
- Maths: for all strongly ferromagnetic objects (iron, steel, nickel, etc.) the value of magnetic susceptibility does not matter. They are all subject to the same amount of force and are equally dangerous in the MR environment

- Myth: titanium is a safer implant material than 316LVM stainless steel
- Maths: the mechanical forces on a similar implant made from either material are negligible. However, titanium has a higher electrical conductivity and will be more susceptible to heating
- Myth: the most common fatal accidents in MRI arise from pacemaker malfunction or projectiles
- Maths: according to recent incident records in the USA (the MAUDE database¹), implantable infusion pump malfunction is currently the most common cause of fatal accidents caused by MRI

LAYOUT OF AN MRI DEPARTMENT

- The American College of Radiology has defined four safety zones within MRI facilities
- These are denoted Zones I through IV and correspond to levels of increasing magnetic field exposure (and hence potential safety concern)



MRI SAFETY ZONES

- The rationale behind the ACR's 4-zone strategy is to make it difficult for unqualified staff and unscreened patients to reach the potentially dangerous inner sanctum of the MRI Center (Zone IV)
- If carefully adhered to, these restrictions should minimize the risk of two major hazards of MRI:
 - a) projectile accidents and
 - b) injury to patients with implanted devices

MRI	
MRI ZONE I	MRI Access Area

- All areas freely accessible to the general public without supervision
- Magnetic fringe fields in this area are less than 5 Gauss (0.5 mT)

- Still a public area, but the interface between unregulated Zone I and the strictly controlled Zones III and IV
- MR safety screening typically occurs here under supervision

NOTICE	
MRI ZONE II	MRI Patient Screening and Preparation



- An area near the magnet room where the fringe, gradient, or RF magnetic fields are sufficiently strong to present a physical hazard to unscreened patients and personnel

- Synonymous with the MR magnet room itself
- Has the highest field (and greatest risk) and from which all ferromagnetic objects must be excluded



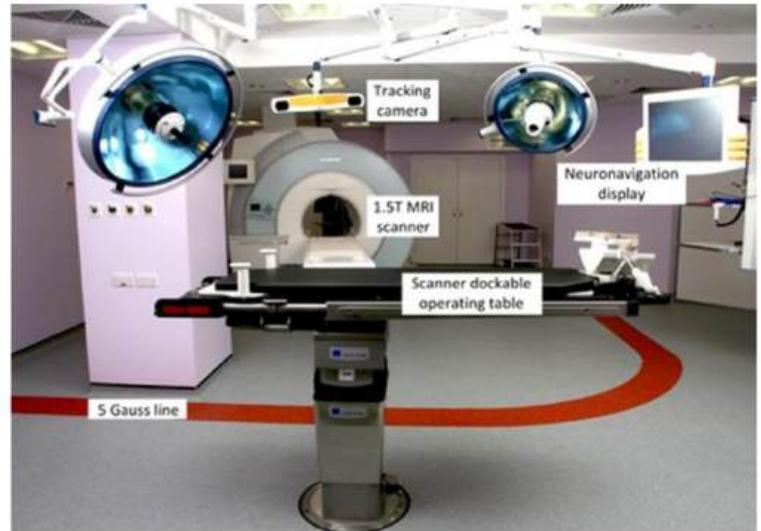
PATIENT AND STAFF SAFETY

SAFETY SCREENING, CONTRAINDICATED MATERIALS AND MRI CONTRAST AGENTS

DEFINITIONS

- **MRI Safe** means that an object or device, when used in the MR environment, will present no additional risk to the patient but may affect the quality of the diagnostic information.
- **MRI Compatible** means that an object or device, when used in the MR environment, is MR safe and will not significantly affect the quality of the diagnostic information, nor will its operation be significantly affected being in the MR environment
- **The 5G (gauss) limit** defines the 'safe' level of static magnetic field exposure.
- It specifies the perimeter around an MR scanner within which the static magnetic fields are higher than fivegauss.
- 5 gauss and below are considered 'safe' levels of static magnetic field exposure for the public.

5-GAUSS LINE IN AN MRI ROOM AND IN AN OPERATING ROOM



SCREENING AND SAFETY PROCEDURES

- Ideally a safety screening form should be used to screen patients and individuals going into the MRI magnet room
- This is to ensure that important safety concerns have been addressed and documented
- This becomes very critical should any incident occur
- Loose items such as jewelry, bank cards, coins, pens etc. should be removed before entering the room
- Unmovable items such as splints must be thoroughly checked for safety with a hand-held bar magnet before entering the MRI magnet room

MRI STAFF SAFETY

- Permanent MRI personnel such as radiographers, radiologists and administrative staff need to complete the safety questionnaire form on their first visit to the unit
- Other hospital staff members such as doctors, nurses, porters etc. must complete the safety questionnaire form and adhere to safety regulations at every visit
- In shielded magnets, radiographic and radiological staff are not usually exposed to the static magnetic field when in the control room
- In unshielded , high field strength magnetic field facilities, staff members may sit in a magnetic field of 30G or more
- However, there is no evidence to suggest that this is harmful in any way
- Exposure to gradients and radiofrequency fields only occurs during the scan sequence and therefore staff are not usually subjected to it
- There are however instances where a staff member is needed to be in the magnet room during the scan and these instances may include;
- patient reassurance
- During dynamic imaging where contrast media is injected during the sequence (in the absence of an automatic pump injector)
- General anesthesia or sedation where the patient needs careful monitoring
- During interventional procedures such as biopsies
- The potential for harmful effects of these conditions have not been fully researched but at present some exposure to changing fields on an occasional basis is not thought to be harmful

MRI PATIENT SCREENING

- Conscious, mentally stable, non-emergent patients, research and volunteer subjects are to complete written MR safety screening questionnaires prior to their introduction to Zone 3
- These completed MR safety screening questionnaires are then to be orally reviewed in their entirety with the patient, guardian, or research subject prior to permitting the individual clearance into Zone 3
- The patient, guardian, or research subject and the screening MR staff member must both sign the completed form.
- This form should then become part of the individual's medical record.
- No empty responses are accepted, and each question must be answered with a yes or no, or specific further information must be provided as requested

MRI SAFETY ON PREGNANT PATIENTS

- Currently, there are no known biological effects of MRI on fetuses
- However, there are a number of mechanisms that could potentially cause adverse effects as a result of the interaction of the electromagnetic fields with the developing fetus
- Cells undergoing division during the first trimester of pregnancy are more susceptible to these effects
- As yet, there are no official guidelines and so MRI is neither recommended nor forbidden, however, it could be suggested that the pregnant patient delays the scan until after the first trimester

The American College of Gynecology and Obstetrics recommends that pregnant patients should be reviewed on a case-to-case basis, and the risk-benefit ratio needs to be made by the physicians involved

There are no known biological effects of MRI on fetuses however Gadolinium should be avoided when examining a pregnant patient

Other precautionary measure that should be taken into consideration should a pregnant patient be subjected to an MRI scan are that the radiographer should only perform important sequences,

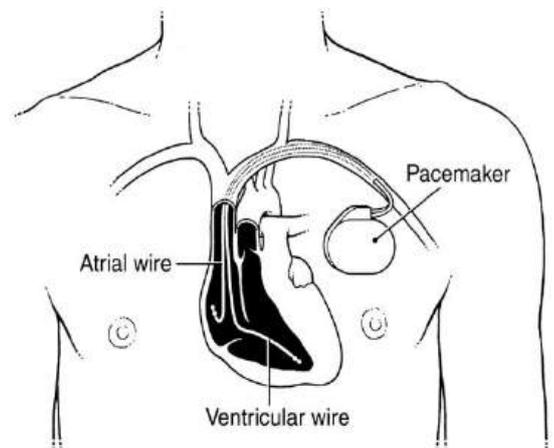
use short scan time protocols or reduce the TR while adjusting other parameters to maintain good quality images

WHAT DO WE LOOK FOR WHEN WE SCREEN PATIENTS AND PERSONNEL FOR MRI SAFETY?

- Cardiac Pacemakers
- Cochlear Implants
- Intracranial aneurysm clips
- Metallic implants and Prosthesis
- Prosthetic heart valves
- Intraocular ferrous foreign bodies
- Orthopedic Implants
- Abdominal surgical clips
- Tattoos
- Implanted neuro-stimulators
- Implanted spinal fusion stimulators

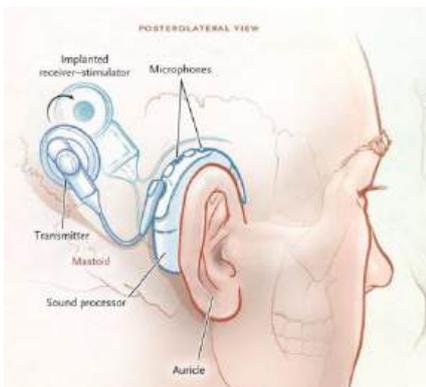
CARDIAC PACEMAKERS

- Even fields as low as 10G may be sufficient to cause deflection, programming changes and closure of the reed switch that converts a pacemaker to an asynchronous mode
- In addition to this, patients who have pacemakers removed, may have pacer wires left within the body that could act as an antenna and by induced currents cause cardiac fibrillation



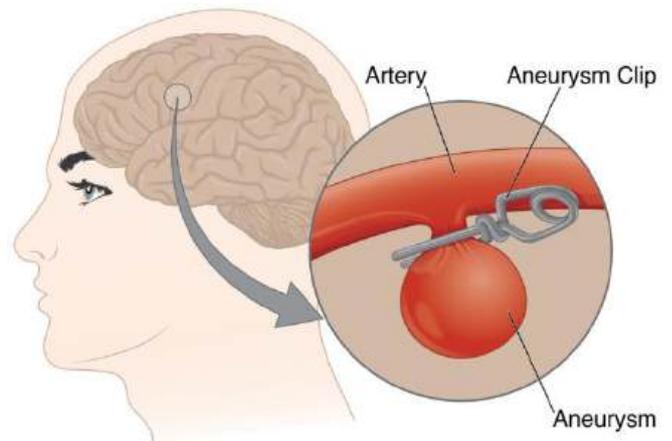
COCHLEAR IMPLANTS

- These are attracted to the magnetic field and are magnetically or electronically activated



INTRA-CRANIAL ANEURYSM CLIPS

- Clip motion may damage the vessel, resulting in haemorrhage, ischemia or death
- Currently many intra-cranial clips are made of a non-ferromagnetic substance such as titanium, however recent studies have indicated that even these may deflect in a magnetic field
- Therefore it is very important to verify the type of aneurysm clip the patient has in order to check is it is non-ferrous and non-deflectable before scanning the patient



INTRA-CRANIAL ANEURYSM CLIPS

- In addition, the following information about the clip should be provided in the labeling by the manufacturer: manufacturer; type (ferromagnetic, weakly ferromagnetic, or non-ferromagnetic); material or alloy; lot number; and model and/or serial number.
- The implanting surgeon should communicate this information for documentation in the patient's records. Any clip that displays ferromagnetic qualities is considered to be contraindicated for MRI
- Aneurysm clips made from “non-ferromagnetic” or “weakly ferromagnetic” materials have been reported in the literature as “MR safe” or “MR compatible”.
- The materials used for these aneurysm clips include commercially pure titanium, titanium alloy, Elgiloy, MP35N, and Phynox.
- An aneurysm clip that is in its original package and made from these materials or others known to be “non-ferromagnetic” or “weakly ferromagnetic” does not need to be evaluated for ferromagnetism

METALLIC IMPLANTS AND PROSTHESIS

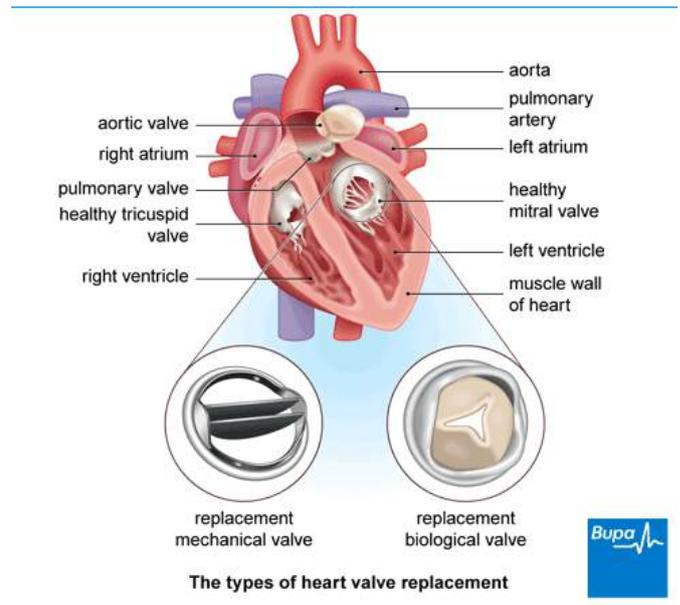
- These produce serious effects which may include torque or twisting in the magnetic field, heating effects and artefacts on MR images
- The type of metal used in such implants is one that determines the force exerted on them in the magnetic field
- While non-ferrous metallic implants may show little or no deflection to the field, they could still cause significant heating due to their inability to dissipate the heat caused by radiofrequency absorption

Metallic Implants



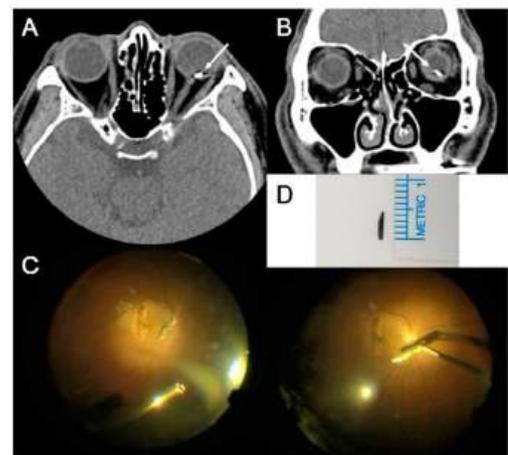
PROSTHETIC HEART VALVES

- Considerably deflected by static magnetic field
- The deflection however is minimal compared with normal pulsatile cardiac motion
- Although patients with most valvular implants are considered safe for MR, there are valves whose integrity is compromised and therefore careful screening of valve type is recommended



INTRA-OCULAR FERROUS FOREIGN BODIES

- Patients who have worked with sheet metal may have metal fragments or slivers located in and around the eye
- Since magnetic field exerts a force on ferromagnetic objects, a metal fragment in the eye could move or be displaced and cause injury to the eye or surrounding tissue
- Therefore patients with suspected metal fragments in the eye must be X-rayed and cleared by the radiologist before an MRI procedure is done



ORTHOPEDIC IMPLANTS



- Most orthopedic implants show no deflection within the main magnetic field
- However a large magnetic implant such as hip prosthesis can become heated by currents induced in the metal by the magnetic and radiofrequency fields, however this heating appears to be very low
- The majority of orthopedic implants have been imaged in MRI without incidents
- It is however recommended that the MRI examination

be done 6 weeks after the surgery

ABDOMINAL SURGICAL CLIPS

- These are generally MR safe because they become anchored by fibrous tissue but produce artefacts in proportion to their size and can distort the image

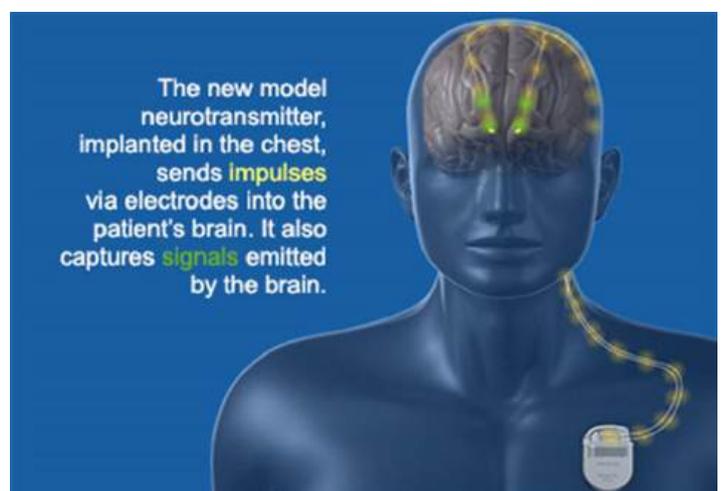


IMPLANTED NEUROSTIMULATORS:

- Concerns about MR safety and compatibility for patients with implanted neuro-stimulators are reported to be specifically related to the RF and gradient fields used in MR procedures because they may interfere with the operation of these devices.
- Malfunction of the device due to exposure to the electromagnetic fields of an MR system could potentially cause pain or discomfort to the patient or damage to the nerve fibers at the site of the implanted electrodes of the neuro-stimulator.
- Additional concerns include the potential for heating of the neuro-stimulator, its leads, or its lead tips and/or subsequent thermal injury to surrounding tissue.
- With regard to gradient field, the closer the lead is to the center of the bore, the less the potential for induced current (Current induction increases toward the periphery of the bore).
- Heating due to RF deposition may be a concern for imaging sequences that employ multiple 180°RF pulses such as TSE or FSE.
- In addition, direct neuro-stimulation may result from rapidly pulsed (changing) gradient magnetic fields utilized in imaging sequences such as EPI that is not limited by the RF coil used.
- Therefore, this concern exists even if a transmit/receive head coil is used to image the brain.

IMPLANTED NEUROSTIMULATORS:

- There are two basic types of implanted neuro-stimulators used in the treatment of various forms of neurological disorders (eg, seizures, epilepsy): passive receivers and hermetically encased pulsed generators.
- Passive receivers receive RF energy that is magnetically coupled from an external device by means of a coil placed over the implanted device.
- Pulse generator neuro-stimulators usually contain a battery and are programmed by an external device to produce the desired stimulus.



IMPLANTABLE SPINAL FUSION STIMULATOR

- The implantable spinal fusion stimulator made by Electro-Biology has recently received approval from the FDA designating it to be “MR-safe” as long as specific guidelines are followed provided by the manufacturer in the product insert labeling
- This device consists of a generator, which includes a battery and electronics in a titanium shell, and is implanted near the area of treatment of the spine
- Two wire leads are connected from the generator to the fusion sites, where they are embedded in pieces of bone grafts. The device remains in place for approximately 24–26 weeks
- An implantable spinal fusion stimulator is used to enhance and facilitate the rate of bone healing

IMPLANTABLE SPINAL FUSION STIMULATOR

The outcome of safety tests recently conducted on the implantable spinal fusion stimulator plus additional experience in scanning large numbers of patients with these devices indicates that MRI examinations may be performed if specific safety guidelines are followed. These guidelines include the following (1, 49-53):

1. The electrodes of the implantable spinal fusion simulator must be positioned a minimum of 10 mm from nerve roots to decrease the potential for excitation.
2. Plain films must be obtained prior to the MR procedure to verify that there are no broken leads present.

If this cannot be determined, the risks and benefits of the MR examination to the patient must be given the utmost consideration as the possibility exists for excessive heating to develop in the leads of the stimulator.

3. MR examinations must only be performed in systems with fields of 1.5 T or less, and only with conventional imaging techniques such as SE, TSE, FSE, or gradient echo (GRE, SPGR, etc.). Pulse sequences or conditions that produce exposures to high levels of RF energy (ie, exceeding a whole-body-averaged SAR of 1.0 W/kg) or exposure to gradient fields that exceed 20 T/sec (eg, EPI), or any other unconventional MR technique, should be avoided.

4. Patients must be continuously monitored during the MR examinations and instructed to report any unusual sensations including any feelings of warmth, heating, peripheral nerve stimulation, or neuromuscular excitation.



*SpF Implantable spine fusion stimulator
(Direct current technology)*

PASSIVE AND ACTIVE IMPLANTS

- Passive implants do not require an external power source. Examples include aneurysm clips, stents, hip prostheses, catheters, electric leads, external fixation devices, and IVC filters.
- MRI may affect implants through a wide range of mechanisms
- All risks associated with passive implants (displacement, rotation, heating, and magnetization) apply to active implants as well, but active implants have additional risks

DEVICE SAFETY DEFINITIONS

- For safety purposes, biomedical implants and devices that might be used in the MRI environment have been classified into three groups since 2005 by the American Society for Testing and Materials (ASTM) International (Standard F2503-20):
- These three groups are MRI safe, MRI conditional and MRI unsafe



MR SAFE

The device/implant is non-magnetic, non-conductive, and does not react to MR levels of radiofrequency irradiation. Its presence poses no risk to patients or staff in the MRI environment.



MR CONDITIONAL

The device/implant *does* contain magnetic, conductive or RF-reactive components, but is deemed safe for use in the MRI environment provided certain strict conditions are followed.



MR UNSAFE

The device/implant contains ferromagnetic materials or has such a response to electromagnetic irradiation that it poses potential harm to MRI patients or staff under all circumstances.

DEVICE SAFETY DEFINITIONS

- The terms MR Safe and MR Unsafe are self-explanatory, but MR Conditional encompasses a wide range of implants and devices deemed safe only under limited conditions
- Typical conditions may include limits on field strength, field spatial gradient, gradient strength, gradient rate, specific absorption rate etc.
- Check the following website for more information on implants and safety: MRISafety.com and MagResource.com

MR Safety Issue	Summary Recommendations
General Safety Topics	
Metallic foreign body in orbit	Screen with 2-view orbit x-rays or low-dose CT; do not scan if metal is in contact with globe or in retro-orbital region
Pellets/Bullets	Confirm location and shape by x-ray or CT. If embedded in muscle or bone, generally OK to scan regardless of composition. Many shotgun pellets and military bullets are ferromagnetic, and could pose a danger of movement if located in critical locations (like brain, lung, on near major vessels). Heating is not a concern.
Shrapnel	Confirm location and shape by x-ray or CT. Try to establish material by history. Usually encased by scar and OK to scan, but caution ferromagnetic shrapnel in critical locations (like brain, lung, on near major vessels). Elongated pieces more dangerous.
Pregnancy	Physician should discuss benefits/risks with patient personally; avoid gadolinium if at all possible
Surgical clips/staples/mesh	OK to scan, even immediately after surgery
Tattoos or body piercings	Remove piercing if possible; warn patient about possible heating
Orthopedic hardware (pins, plates, screws, wires, rods, joint replacements)	Generally OK to scan, expect moderate to large metal artifact
Dentures, partial plates, braces	Generally OK to scan if non-magnetic and secure, but remove if possible for head scans to reduce artifact
Contraceptive IUD or diaphragm	Generally OK to scan
Medication patch	Metal-backed patches may cause burns and should be removed
Insulin pump	All are MR Unsafe, must be removed
Artificial or prosthetic limb	All are MR Unsafe, must be removed
Hearing aid	All are MR Unsafe, must be removed
Watches, rings, jewelry, glasses, hairpins	Remove; why take a chance?
Implanted drug infusion pump	Some are MR Conditional, others MR Unsafe
Street clothing and underwear	Remove and provide hospital gown; reduces chances of small objects like hairpins or paperclips being brought into scanner; also some clothing materials contain metal fibres that may cause burns

Neurologic/Head and Neck Safety Topics	
Aneurysm clip	Nearly all implanted in last 20 years are non-ferromagnetic and OK to scan, but still wise to confirm model; older clips need very careful identification
Cerebrospinal shunts and drains	Nearly all are OK to scan; programmable shunt pressures must be checked after scanning
Intracranial bolts/pressure monitors	Most are MR Conditional
Epidural catheters	Most are MR Unsafe due to wire reinforcement or imaging only with a transmit-receive head coil
Neurostimulators (brain, spinal cord, peripheral nerve)	Many newer models are MR Conditional; older units MR Unsafe
Cochlear and other ear implants	Some newer models are MR Conditional, others MR Unsafe

Thoracic and Cardiovascular Safety Topics	
Vascular stents, filters, and coils	OK to scan immediately after implantation
Cardiac valves & annuloplasty devices	OK to scan immediately after implantation
Cardiac pacemaker or defibrillator	Newer models can be scanned under specific conditions only; many older (non-conditional) models may also be scanned under even more restrictive protocols
Temporary Transvenous Pacemaker	MR Unsafe, must be removed
Retained epicardial pacing wires	Broken off wires OK to scan
Vascular access port	Nearly all are non-ferromagnetic and OK to scan immediately after implantation
Abandoned vascular lead	Probably should consider as MR unsafe, but some controversy depending on clinical scenario
Loop recorder	Most common types are MR Conditional; download data before scanning
Tissue expander (e.g. breast)	Nearly all have magnetic ports and are MR Unsafe

Abdomen and Musculoskeletal Safety Topics	
Penile implants	OK to scan
PillCams	Avoid scanning while in GI tract, but doubtful harm if you do
Foley catheters	OK to scan, but special attention to those with temperature probes that are MR Conditional
Halo and external fixation devices	OK but must be sure they are rated as MR-compatible
Bone fusion stimulators	MR Conditional
Gastric pacemakers	MR Unsafe

GADOLINIUM BASED CONTRAST AGENTS (GBCA)

- MRI signal enhancement using gadolinium-based contrast agents (GBCAs) is an important supplement to unenhanced MRI for the diagnosis of numerous conditions in multiple body systems,
- Particularly in neurological, oncology and cardiovascular imaging.
- GBCAs, while proven generally safe, are not entirely risk free and an understanding of the risks and mitigations is required.

GADOLINIUM BASED CONTRAST AGENTS (GBCA)

- During the early 2000s, a serious condition called nephrogenic systemic fibrosis (NSF) was discovered and linked to the use of GBCAs in patients with severe kidney disease.
- This was proven to be an adverse effect of certain GBCA which released free gadolinium in the body.
- Updated guidance relating to kidney disease and the risk stratification of the GBCAs, led to a rapid reduction and subsequent disappearance of NSF.
- A common approach in the UK was a clinical decision to switch from high or medium risk GBCAs to low risk GBCAs where possible.

NSF AND GADOLINIUM RETENTION

- In 2014, reports of retained gadolinium in the brain following multiple doses of GBCA started to appear.
- At this point, pharmacovigilance action by the European Medicines Agency (EMA) and Medicines and Healthcare products Regulatory Agency (MHRA), restricted the use of GBCAs according to their risk profile.
- High risk GBCAs (e.g. gadopentetate and gadodiamide) are no longer available for intravenous use.
- Medium risk GBCAs (e.g. gadoxetate and gadobenate) are restricted to delayed phase liver imaging only.
- Only low-risk GBCAs (e.g. gadobutrol, gadoteric acid, gadopicolenol) are available for general MRI.

PRESCRIBING AND PROTOCOLLING

- Risk-benefits assessment is needed when prescribing a GBCA and involves identifying patients at increased risk from contrast, consent and those with previous contrast reaction, multiple allergies or renal disease.
- Check for kidney function tests (i.e. eGFR and creatinine)
- Formal documentation of the decision to administer a GBCA must be kept.
- Patient consent is an important part of medical care.
- The individual administering the GBCA must confirm consent and ensure that the patient understands and agrees.
- Appropriate patient information leaflets should be available.

POSSIBLE SIDE EFFECTS/ REACTIONS DUE TO GBCA

- Acute reactions to GBCAs include nausea and vomiting, urticaria, bronchospasm, laryngeal oedema, hypotension and generalized anaphylactic reaction.
- RCR guidelines provide treatment algorithms for the management of these reactions.
- It can be helpful to have treatment protocols readily available (e.g. in poster form) within the MR department.
- Extravasation in MRI is typically mild and can be treated with elevation and advice.
- Where symptoms do not resolve quickly, or there are features such as skin blistering, paresthesia, worsening or severe pain or evidence of altered perfusion, then specialist advice should be sought as an emergency.

LEARNING POINTS

- The magnet is always "ON"
- Ensure safety screening of each and every person before going into the MRI room (from cleaners, porters, medical staff, colleagues, patients and chaperones)
- Have the evidence of safety screening (have a standardized form with listed ferromagnetic items and relevant questions for everyone to complete as a requirement before going in the MRI room)
- This should be kept in record
- Pregnant patients should not be given GBCA
- Scans can be done after the first trimester, with limited sequences and at reduced time to repeat (TR)

QUESTIONNAIRE
A13(25) Part 1 of 4
MRI instrumentation and safety

INSTRUCTIONS

- Read through the article and answer the multiple-choice questions provided below.
- **Some questions may have more than one correct answer;** in which case you must mark **all** the correct answers.

Question 1: In the event of loss of superconductivity, electrical energy is dissipated as..... ?

- A:** Helium gas
- B:** Liquid
- C:** Heat
- D:** Carbon dioxide

Question 2: Quenching is the process where there is a sudden loss of absolute zero of temperature in the magnet coils. This means that.....?

- A:** They cease to be super-conducting, and they become resistive
- B:** They lose energy and stop functioning
- C:** The helium gas is released
- D:** The super-conducting coils reach a freezing point temperature

Question 3: The function of an oxygen monitor in the MRI room is to?

- A:** Ensure that there is sufficient oxygen in the room for patients and staff
- B:** Sound an alarm if the oxygen level falls below a certain level
- C:** Replace the helium gas if it exceeds the oxygen level
- D:** Monitor the helium gas levels in the MRI room

Question 4: Specific Absorption Rate (SAR) depends on the following factors?

- A:** Duty cycle and transmitter-coil type, field strength, radio frequency power, and body size.
- B:** MRI signal, RF power, body weight and the direction of magnetic field
- C:** Magnetic field strength, magnetic field direction, body weight and duty cycle
- D:** Duty cycle, RF power, magnetic field direction and body weight

Question 5: What is the purpose of the RF coils in MRI?

- A:** To induce eddy currents
- B:** To generate magnetic field gradients
- C:** To create the static magnetic field
- D:** To transmit and receive radiofrequency waves for excitation and signal detection

Question 6: Which type of RF coil design has a better signal-to-noise ratio in MRI?

- A:** Birdcage RF coils
- B:** Surface RF coils
- C:** Linear RF coils
- D:** Quadrature RF coils

Question 7: What are the advantages of superconducting electromagnets used in MRI?

- A:** They are lightweight and portable
- B:** They have low energy consumption
- C:** They produce strong, homogeneous magnetic fields
- D:** They are cheaper and easier to maintain than resistive electromagnets

Question 8: What are the components of the radiofrequency system in MRI?

- A:** Shim coils
- B:** Transmit and receive coils
- C:** Gradient coils
- D:** Main magnet

Question 9: What is the potential safety concern associated with RF stimulation in MRI?

- A:** Gradient-induced eddy currents
- B:** Projectile accidents
- C:** Electromagnetic interference
- D:** Tissue heating

Question 10: What is the most significant biological effect of RF stimulation in MRI?

- A:** Nerve stimulation
- B:** Acoustic noise
- C:** Tissue heating
- D:** Magneto phosphenes

Question 11: What is the potential risk of using metallic objects in the MRI environment?

- A:** They may affect the static magnetic field
- B:** They may cause heating due to radiofrequency pulses
- C:** They may cause acoustic noise
- D:** They may induce eddy currents

Question 12: What are the safety zones defined within an MRI facility

- A:** Zones I, II, III, and IV
- B:** Zones Safe, Caution, Warning, and Danger
- C:** Zones Primary, Secondary, Tertiary, and Quaternary
- D:** Zones A, B, C, and D

Question 13: What is the purpose of a Faraday cage in MRI?

- A:** To insulate the MRI device from external RF signals
- B:** To shield the MRI room from magnetic fields
- C:** To control the acoustic noise in the MRI environment
- D:** To prevent electromagnetic interference

Question 14: What is the purpose of magnetic field gradients in MRI?

- A:** To generate radiofrequency waves
- B:** To induce acoustic noise
- C:** To produce variations in the magnetic field
- D:** To encode the signal spatially

Question 15: What is the role of the main magnet in MRI?

- A:** To encode the signal spatially
- B:** To create the static magnetic field
- C:** To produce acoustic noise
- D:** To generate radiofrequency waves

THE END

QUESTIONNAIRE
A13(25) Part 2 of 4
MRI instrumentation and safety

INSTRUCTIONS

- Read through the article and answer the multiple-choice questions provided below.
- **Some questions may have more than one correct answer;** in which case you must mark **all** the correct answers.

Question 1: Oxygen levels are slowly depleting when they reach.....?

- A:** 19.6% or below
- B:** 21.5% or below
- C:** 15% or below
- D:** 30.6% or below

Question 2: Liquid helium is used to cool down the superconductive magnets coil in MRI scanners to a temperature

- A:** Below 5 Kelvin
- B:** Below 10 Kelvin
- C:** Above 10 Kelvin
- D:** Above 5 Kelvin

Question 3: One of the disadvantages of the low field MRI Resistive electromagnets is that they

- A:** Are very heavy and weak in intensity
- B:** Are very expensive
- C:** Are difficult to maintain
- D:** Use less energy

Question 4: What produces variations in magnetic field signal intensity?

- A:** Pairs of coils, placed in each spatial direction.
- B:** A single coil, placed in the opposite spatial direction
- C:** Pairs of coils placed randomly
- D:** Pairs of coils only

Question 5: There are several methods to reduce the effects of the induced currents and one of them is

- A:** Passive gradient coil shielding
- B:** Optimizing the electric current profile sent to the gradient coils while ascending and descending to offset the Eddy currents
- C:** Coil tuning
- D:** Switching the coils off

Question 6: What is the risk for a patient whose hand, shoulder, or other body part touches the scanner walls (or comes close in these hot spots)?

- A:** They risk having cutaneous burns
- B:** They risk RF burns
- C:** They risk receiving an increased SAR
- D:** They risk having a ferromagnetic injury

Question 7: What is the first step in the optimization of the radiofrequency channel prior to an imaging sequence?

- A:** Adjusting the transmission power
- B:** They risk RF burns
- C:** They risk receiving an increased SAR
- D:** They risk having a ferromagnetic injury

Question 8: What is the first step in the optimization of the radiofrequency channel prior to an imaging sequence?

- A:** Adjusting the transmission power
- B:** Setting the exact Larmor frequency
- C:** It is adjusted according to the weight of the patient
- D:** It is set based on the transmit coil

Question 9: What factor influences the adjustment of transmission power during the optimization process?

- A:** The patient's height
- B:** The patient's weight and the transmit coil
- C:** The magnetic field strength
- D:** The desired signal-to-noise ratio

Question 10: Why is the receiver gain adjusted during the optimization process?

- A:** To set the exact Larmor frequency
- B:** To obtain the desired flip angles
- C:** To avoid signal saturation or weak amplification
- D:** To calibrate the imaging sequence

Question 11: What is the consequence of weak amplification in the receiver gain adjustment?

- A:** Signal saturation
- B:** Deteriorated signal-to-noise ratio
- C:** Incorrect Larmor frequency
- D:** Excessive transmission power

Question 12: What does the specific absorption rate (SAR) describe?

- A:** The potential for cooling of the patient's tissue
- B:** The potential for heating of the patient's tissue due to the application of RF energy
- C:** The magnetic field strength
- D:** The signal-to-noise ratio

Question 13: How is the specific absorption rate (SAR) measured?

- A:** Joules per second (J/s)
- B:** Watts per kilogram (W/kg)
- C:** Volts per meter (V/m)
- D:** Amperes per square meter (A/m²)

Question 14: What factors influence the absorbed dose of RF energy?

- A:** Duty cycle and transmitter-coil type
- B:** Magnetic field strength and signal-to-noise ratio
- C:** Patient's age and gender
- D:** Imaging sequence and scan duration

Question 15: Which of the following increases the absorbed dose of RF energy?

- A:** Decreased field strength
- B:** Lower radio frequency power
- C:** Smaller body size
- D:** Increased field strength, radio frequency power, and body size

THE END

QUESTIONNAIRE
A13(25) Part 3 of 4
MRI Patient and Staff safety

INSTRUCTIONS

- Read through the article and answer the multiple-choice questions provided below.
- **Some questions may have more than one correct answer;** in which case you must mark **all** the correct answers.

Question 1: What is the current stance regarding MRI scans on pregnant patients?

- A:** MRI scans can be performed with certain safety protocols during the second trimester
- B:** MRI scans are considered safe at any stage of pregnancy
- C:** MRI is neither recommended nor forbidden, but it is suggested to delay scans until after the first trimester
- D:** MRI scans should not be performed on pregnant patients

Question 2: What type of aneurysm clips are considered contraindicated for MRI?

- A:** Clips made from non-ferromagnetic or weakly ferromagnetic materials
- B:** Clips made from commercially pure titanium or titanium alloy
- C:** Clips made from materials known to be 'MR safe' or 'MR compatible'
- D:** Clips made from ferromagnetic materials

Question 3: Why should metallic implants and prostheses be carefully evaluated before an MRI scan?

- A:** To ensure they have been thoroughly checked for safety with a hand-held bar magnet
- B:** To check their compatibility with the MR environment
- C:** To determine the type of metal and potential risks such as heating or image artifacts
- D:** To prevent them from causing deflection and closure of cardiac pacemakers

Question 4: Why should loose items such as jewelry and pens be removed before entering the MRI room?

- A:** To prevent deflection and closure of pacemakers or asynchronous mode
- B:** To prevent them from being attracted to the magnet and causing injury or damage
- C:** To avoid interference with the operation of implanted neuro-stimulators
- D:** To prevent them from flying all over the MRI room

Question 5: What should MRI staff members do to ensure their safety in shielded magnets?

- A:** Undergo continuous monitoring during the MRI examinations
- B:** Sit in a magnetic field of 30G or more
- C:** Screen patients and individuals using a safety screening form
- D:** Complete a safety questionnaire form on their first visit to the unit

Question 6: What are the three classifications of biomedical implants and devices in relation to MRI safety?

- A:** MR Inert, MR Magnetic, and MR Retained
- B:** MR Non-reactive, MR Ferromagnetic, and MR Safe
- C:** MR Safe, MR Compatible, and MR Unsafe
- D:** MRI Safe, MRI Conditional, and MRI Unsafe

Question 7: What type of implantable neuro-stimulators can be MR Conditional?

- A:** Older models that are proven to be MR Unsafe
- B:** Models that are implanted near the area of treatment of the spine
- C:** Newer models that are specifically designed for safe use in the MRI environment
- D:** Models that contain magnetic, conductive, or RF-reactive components

Question 8: What should patients complete before entering Zone 3 of the MRI facility?

- A:** A general imaging safety screening form
- B:** MR safety screening questionnaires
- C:** Read the safety protocols and regulations document and initial each page
- D:** Detailed patient history form

Question 9: When might a staff member need to be in the magnet room during an MRI scan?

- A:** During the administration of gadolinium-based contrast media
- B:** During dynamic imaging where contrast media is injected during the sequence
- C:** During interventional procedures such as biopsies
- D:** During patient screening and safety procedures

Question 10: What does MRI Safe mean?

- A:** An object or device that will not significantly affect the quality of diagnostic information
- B:** An object or device that presents no additional risk to the patient but may affect the quality of diagnostic information
- C:** An object or device that is contraindicated for MRI due to potential harm to patients or staff

Question 11: What information should be included in the labelling of an aneurysm clip by the manufacturer?

- A:** Manufacturer, type, material or alloy, lot number, and model and/or serial number
- B:** Manufacturer, type, patient's name, and date of implantation
- C:** Type, material or alloy, patient's medical history, and model number
- D:** Manufacturer, patient's name, lot number, and date of implantation

Question 12: Who should communicate the information about the aneurysm clip for documentation in the patient's records?

- A:** The radiologist
- B:** The implanting surgeon
- C:** The MRI technician
- D:** The manufacturer

Question 13: What is the MRI compatibility status of aneurysm clips that display ferromagnetic qualities?

- A:** MR safe
- B:** MR compatible
- C:** Contraindicated for MRI
- D:** Safe for all MRI procedures

Question 14: Which materials are used for aneurysm clips that are considered "MR safe" or "MR compatible"?

- A:** Stainless steel and cobalt-chromium
- B:** Commercially pure titanium, titanium alloy, Elgiloy, MP35N, and Phynox
- C:** Aluminium and copper

Question 15: What is the requirement for an aneurysm clip made from non-ferromagnetic or weakly ferromagnetic materials in its original package?

- A:** It must be evaluated for ferromagnetism
- B:** Torque or twisting, heating effects, and artefacts on MR images
- C:** Enhanced image clarity
- D:** Reduced magnetic field strength

THE END

QUESTIONNAIRE
A13(25) Part 4 of 4
MRI Patient and Staff safety

INSTRUCTIONS

- Read through the article and answer the multiple-choice questions provided below.
- **Some questions may have more than one correct answer;** in which case you must mark **all** the correct answers.

Question 1: What serious effects can metallic implants produce in an MRI environment?

- A:** Increased blood flow
- B:** Torque or twisting, heating effects, and artefacts on MR images
- C:** Enhanced image clarity
- D:** Reduced magnetic field strength

Question 2: What determines the force exerted on metallic implants in the magnetic field?

- A:** The size of the implant
- B:** The patient's age
- C:** The duration of the MRI scan
- D:** The type of metal used in the implant

Question 3: How do non-ferrous metallic implants behave in the magnetic field?

- A:** They show little or no deflection but may cause significant heating
- B:** They show significant deflection
- C:** They enhance the magnetic field
- D:** They completely neutralize the magnetic field

Question 4: Why can non-ferrous metallic implants cause significant heating?

- A:** Due to their ability to dissipate heat
- B:** Due to their inability to dissipate the heat caused by radiofrequency absorption
- C:** Because they are magnetic
- D:** Because they are non-magnetic

Question 5: How are heart valves affected by the static magnetic field in an MRI?

- A:** They are considerably deflected
- B:** They enhance the magnetic field
- C:** They neutralize the magnetic field
- D:** They are not affected at all

Question 6: How does the deflection of heart valves in the magnetic field compare to normal pulsatile cardiac motion?

- A:** The deflection is the same as normal cardiac motion
- B:** The deflection is greater than normal cardiac motion
- C:** The deflection is minimal compared with normal pulsatile cardiac motion
- D:** The deflection is negligible

Question 7: Are patients with most valvular implants considered safe for MRI?

- A:** No, they are all considered unsafe
- B:** Yes, most are considered safe
- C:** Only if they are non-ferrous
- D:** Only if they are ferrous

Question 8: What is recommended for valves whose integrity is compromised?

- A:** Careful screening of valve type
- B:** Avoidance of MRI
- C:** Increased MRI frequency
- D:** Immediate replacement

Question 9: What is the primary concern with metallic implants in an MRI environment?

- A:** Increased image resolution
- B:** Potential for heating and artefacts
- C:** Enhanced magnetic field strength
- D:** Reduced scan time

Question 10: What should be done for patients with metallic implants before undergoing an MRI?

- A:** Detailed screening and assessment of the implant type
- B:** Immediate removal of the implant
- C:** Increased MRI scan duration
- D:** No special precautions are needed

Question 11: Why might patients who have worked with sheet metal have metal fragments in and around their eyes?

- A:** Due to exposure to high temperatures
- B:** Due to the nature of their work with sheet metal
- C:** Due to chemical reactions
- D:** Due to prolonged exposure to sunlight

Question 12: What effect does the magnetic field have on ferromagnetic objects in an MRI environment?

- A:** It neutralizes them
- B:** It cools them down
- C:** It exerts a force on them
- D:** It makes them invisible

Question 13: What could happen if a metal fragment in the eye is exposed to the magnetic field during an MRI?

- A:** The fragment could dissolve
- B:** The fragment could become magnetic
- C:** The fragment could enhance the MRI image
- D:** The fragment could move or be displaced, causing injury

Question 14: What must be done for patients with suspected metal fragments in the eye before undergoing an MRI?

- A:** They must be given a sedative
- B:** They must be X-rayed and cleared by a radiologist
- C:** They must wear protective eyewear
- D:** They must fast for 12 hours

Question 15: Why is it important to X-ray and clear patients with suspected metal fragments in the eye before an MRI?

- A:** To enhance the MRI image quality
- B:** To ensure the safety of the patient and prevent injury
- C:** To reduce the MRI scan time
- D:** To increase the magnetic field strength

THE END



MEMBER INFO

(Complete sections marked with an asterisk *)

*FOH number

*HPCSA number

ID number

Personal detail changes

I hereby declare that the completion of this document is my own effort without any assistance.

SIGNED:

DATE:

This activity is accredited for TWELVE (12) CLINICAL CEU'S. You have to achieve 70% to pass this activity.

ANSWER SHEET

A13(25)

MRI Instrumentation and safety

*Time spent on activity											hour					min							
PART 1											PART 2												
	A	B	C	D	E		A	B	C	D	E		A	B	C	D	E		A	B	C	D	E
1					8							1						8					
2					9							2						9					
3					10							3						10					
4					11							4						11					
5					12							5						12					
6					13							6						13					
7					14							7						14					
					15													15					

How relevant was the content of this activity to your scope of practice?			
Not at all	Somewhat	Mostly	Extremely
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

RETURN ANSWER SHEET TO

Online members, complete your answer sheet online

CPD PORTAL: http://foh-cpd.co.za/cpd-online/cpd-user (Username: FOH number & Password: ID)

(Results are available immediately)

Email or hard copy members, complete your answer sheet online or return it to:

WHATSAPP: 074 230 3874 EMAIL: info@foh-cpd.co.za

(Results will be sent via email)

You will receive a confirmation of receipt SMS within 12-24hours, if not received please send again.

Have a suggestion or comment?

Send it to us on EMAIL or WHATSAPP



MEMBER INFO

(Complete sections marked with an asterisk *)

ANSWER SHEET

***FOH number**

***HPCSA number**

ID number

Personal detail changes

I hereby declare that the completion of this document is my own effort without any assistance.

SIGNED:

DATE:

This activity is accredited for **TWELVE (12) CLINICAL** CEU'S. You have to achieve **70%** to pass this activity.

A13(25)

MRI Instrumentation and safety

*Time spent on activity											hour					min							
PART 3											PART 4												
	A	B	C	D	E		A	B	C	D	E		A	B	C	D	E		A	B	C	D	E
1						8						1						8					
2						9						2						9					
3						10						3						10					
4						11						4						11					
5						12						5						12					
6						13						6						13					
7						14						7						14					
						15												15					

How relevant was the content of this activity to your scope of practice?			
Not at all	Somewhat	Mostly	Extremely
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

RETURN ANSWER SHEET TO

Online members, complete your answer sheet online

CPD PORTAL: <http://foh-cpd.co.za/cpd-online/cpd-user> (Username: FOH number & Password: ID)

(Results are available immediately)

Email or hard copy members, complete your answer sheet online or return it to:

WHATSAPP: 074 230 3874 **EMAIL:** info@foh-cpd.co.za

(Results will be sent via email)

You will receive a confirmation of receipt SMS within 12-24hours, if not received please send again.

Have a suggestion or comment?

Send it to us on **EMAIL** or **WHATSAPP**