

MRC

Cognition and
Brain Sciences Unit

MR Safety

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Head of MRI



Overview

Part I: Hazards in MRI

Part II: The MRI Facility at the CBU

Part III: Emergency Procedures

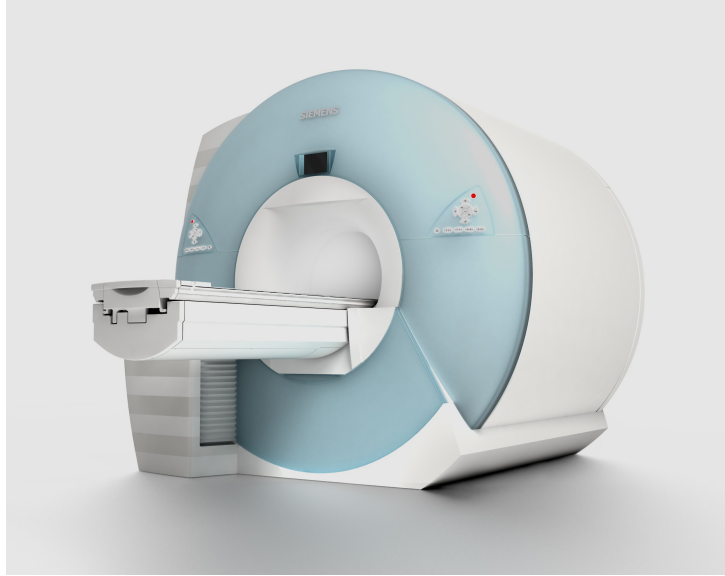
Part I

Hazards in MRI

Hazards in MRI

- Static magnetic field (main magnet)
- Imaging gradient fields
- Radiofrequency fields (RF coils)
- Acoustic noise
- Liquid helium
- MR phantoms

Static Magnetic Field



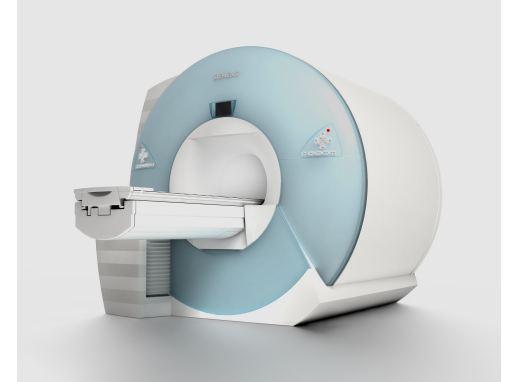
**Siemens TIM TRIO
(3 Tesla)**

- Earth magnetic field: 0.05mT
- Safe magnetic field: 0.5mT = 5 Gauss
(Safe for cardiac pacemakers or other implanted devices)
- Our magnet: 3T = 3000mT
 - 60,000 times the earth magnetic field!
 - 6,000 times the safe magnetic field!

Static Magnetic Field - Risks

The main risks are related to:

2. Loose ferromagnetic objects
3. Ferromagnetic objects in a person's body (e.g. surgical staples; metallic fragments or shavings; shrapnel from war injury)
4. Implanted medical devices (e.g. cardiac pacemaker)

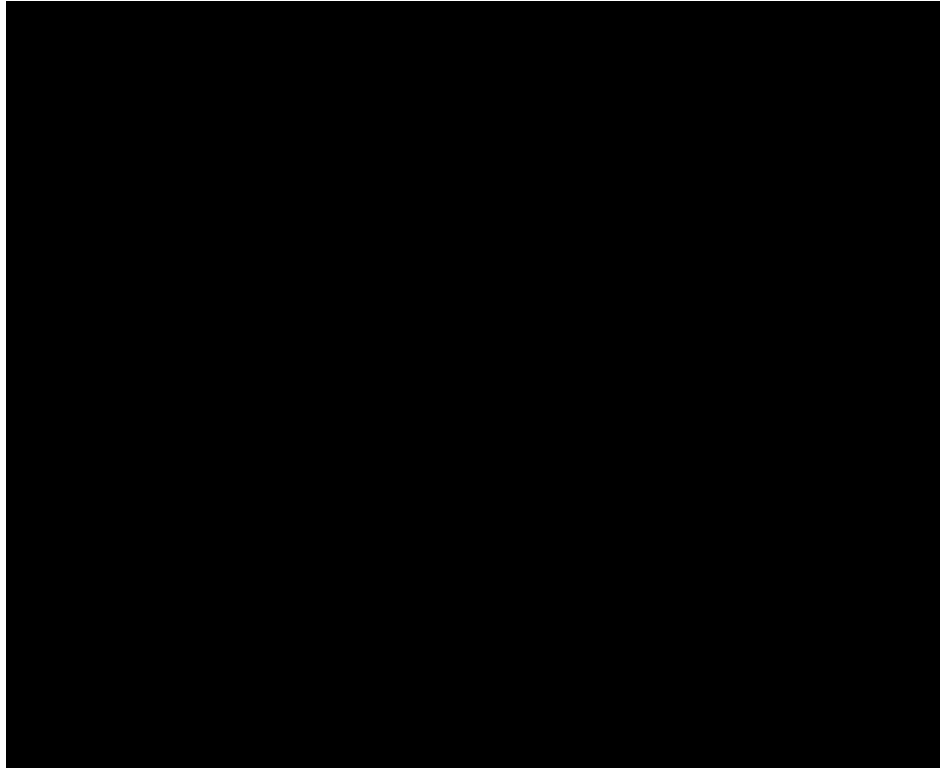


Risk 1: Loose Ferromagnetic Objects



Danger of severe injury or death! Large objects may cause permanent damage to the magnet (cost £500,000)

Risk 1: Loose Ferromagnetic Objects



Danger of severe injury or death!

Risk 2: Ferromagnetic Objects in a Person's Body

Medical implants

- Surgical clips, staples, screws, metal rods, etc
- Artificial limbs or joints
- Metal or wire mesh implants

Foreign metallic objects from accidents or injuries

- Shrapnel or bullets (war injuries)
- Metallic fragments or shavings (metal workers)

Ferromagnetic objects in a person's body can get dislocated by the strong magnetic field.

Danger of severe injury or death!

Risk 3: Implanted Medical Devices

Examples:

- Cardiac pacemakers
- Neurostimulators
- Cochlear implants
- Implanted drug infusion devices

Safe magnetic field: less than 0.5mT = 5 Gauss

Effect of strong magnetic fields:

- Malfunction or failure
- Dislocation

Danger of severe injury or death!

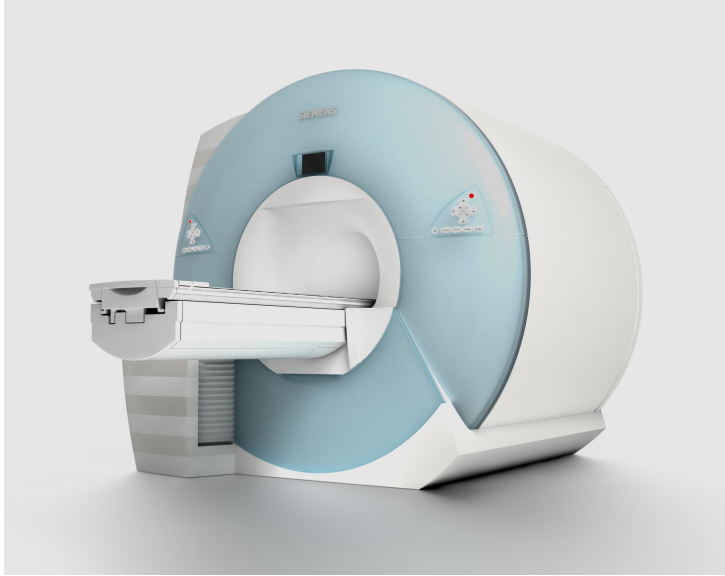
Static Magnetic Field

Safety procedures

- Restricted access to the MRI Facility
- No ferromagnetic objects are allowed in the magnet room
- Only objects labelled MR safe may be taken into the magnet room
- Adequate MR safety screening of volunteers, staff and visitors



Static Magnetic Field



The static magnetic field is always present (24 hours a day, 7 days a week) even when the scanner is not in use!

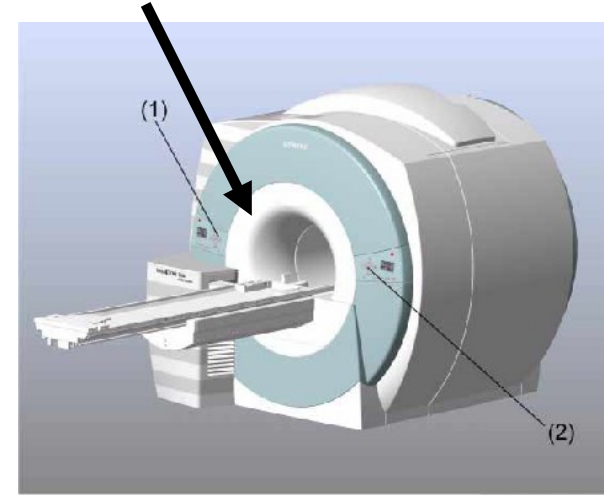
Static Magnetic Field

Bioeffects

- Subjects may temporarily experience slight dizziness or sensory irritations (metallic taste)
- Particularly during table movement
- May be perceived as unpleasant but is not hazardous

Imaging Gradient Fields

- Required for spatial encoding in MRI
- Only active during a scan
- Maximum field strength: $30\text{mT} \ll 3\text{T}$
- Time-varying magnetic field
(switching frequency $< 1000\text{Hz}$)
- Induce electric currents in the body (depending on switching frequency and gradient strength)
- The system is safeguarded by the Gradient Supervision Unit which ensures that the exposure limits are not exceeded



Imaging Gradient Fields

Peripheral nerve stimulation

- May occur at high switching rates (twitching or poking sensation)
- May be perceived as unpleasant but is not hazardous
- In very rare cases, subjects may complain about a relatively strong sensations. In such a case the scan should be aborted immediately and the imaging session should be terminated.

Radiofrequency Fields

- Required for excitation of hydrogen nuclei
- Only active during a scan
- Frequency: 125MHz
Causes eddy currents in conductive media
(e.g. human body, wires, metal objects, etc.)
- Absorption in the human body generates heat
(SAR = Specific Absorption Rate)
- The system is safeguarded by the Radiofrequency Supervision Unit which ensures that the exposure limits are not exceeded



Radiofrequency Fields

Contact Burns

Contact burns are the most often reported adverse incident in MR.

Examples of causes are:

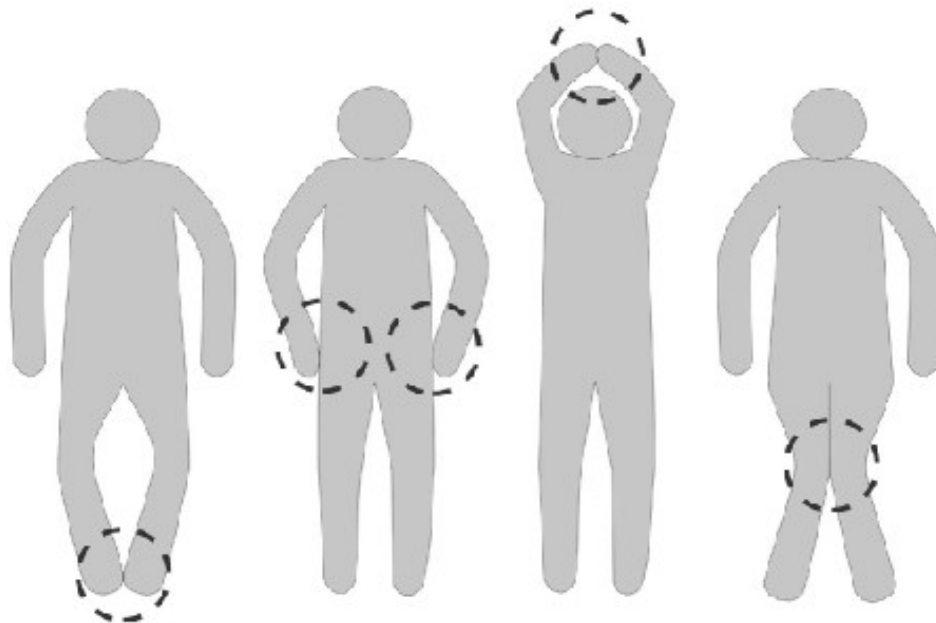
- Contact with metal in clothing
- Contact with electrically conducting jewellery
- Permanent make-up, e.g. permanent eyeliner or eyebrows (may contain metallic particles)
- Tattoos (may contain metallic particles)
- Body piercing
- Nicotine patches
- Loops in conductive cables (e.g. ECG leads)

Radiofrequency Fields

Contact Burns

Induced contact burns

There have been reports of burns that have occurred when the arms or the legs have been positioned in such a way as to create a conductive loop pathway.



Acoustic Noise

- Switching of imaging gradients produces acoustic noise
- Up to 105dB
- Depends on imaging sequence used

Danger of hearing damage!



Adequate hearing protection must be worn during a scan:

Siemens headphones + ear plugs

Liquid Helium

- Used as coolant to keep magnet in superconductive state
- Extremely cold: -269 °C

Main hazards

- **Severe frostbite**
- **Asphyxiation (Helium gas may displace oxygen and result in an oxygen deficient atmosphere)**

During normal operating procedures contact with helium is extremely unlikely, however, accidents have occurred:

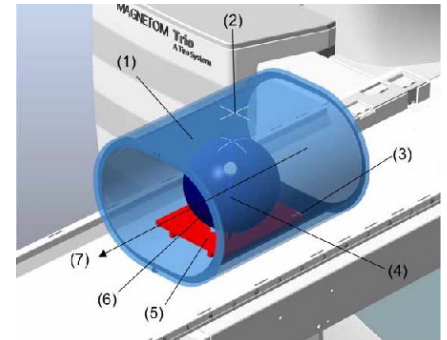
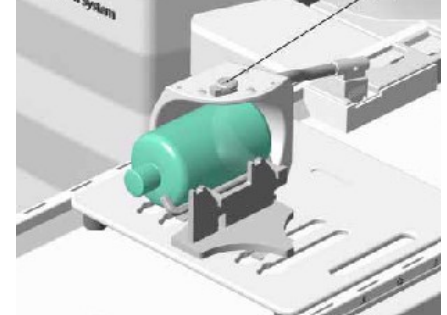
- During a magnet quench (discussed in detail later)
- During helium filling
(may be performed only by Siemens Service)

MR Phantoms

Some phantoms are filled with water-based nickel sulphate solutions.

If phantom fluid has escaped, aerosols containing nickel may form in the event of a fire or by strong air currents.

Carcinogenic effects cannot be ruled out if these aerosols are absorbed by the body.

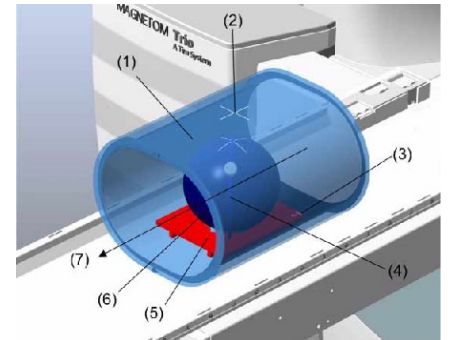
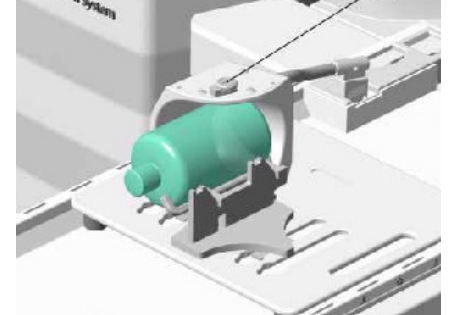


Danger of injury: Avoid contact with phantom fluid!

MR Phantoms

Measures of precaution

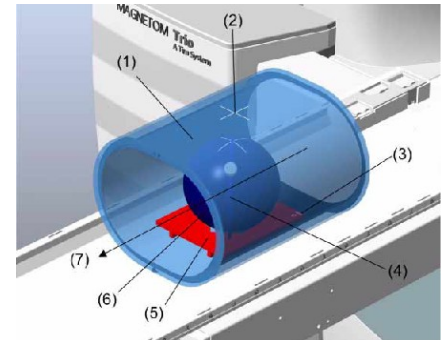
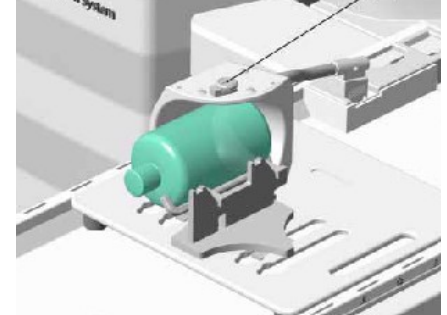
- Do not use damaged phantoms
- Avoid skin contact with phantom fluid
- Inform the supervising radiographer immediately



MR Phantoms

Disposal of damaged phantoms

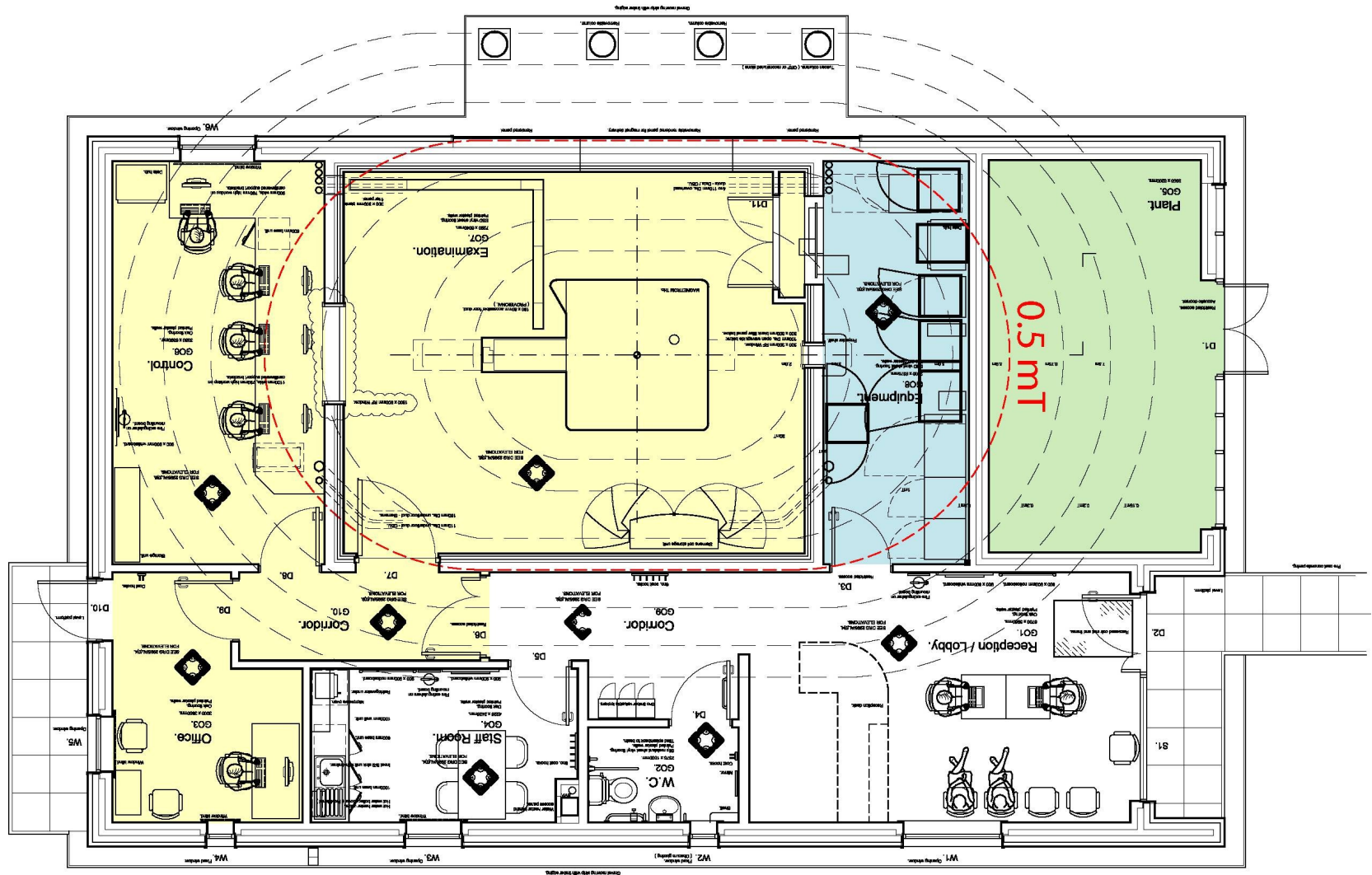
- Wear protective clothing (gloves, work coat, and goggles)
- Wear a suitable breathing mask if aerosols are formed
- Change contaminated clothing immediately
- Ensure that phantom fluid does not enter the waste water



Part II

The MRI Facility at the CBU

Controlled Area



Access to the Controlled Area

Only Authorised Personnel has free access to the Controlled Area (e.g. Radiographer, Head of MRI, Facility Administrator)

A Certified Person will be granted limited access to Controlled Area (everyone who has successfully completed this training course)

Limited access means:

- During normal working hours
- Only in the presence of an Authorised Person (e.g. Radiographer)

Equipment Policy

Only equipment may be taken into the Magnet Room if

- classified as **MR Safe or MR Compatible** by the manufacturer (Siemens Medical, Erlangen, Germany)
- labelled **MR Safe or MR compatible** by an authorised member of staff, following adequate testing.
- Testing and labelling must be approved by the Head of MRI, and a written record must be kept.

Required Staffing Levels

For **scanning volunteers during official opening hours** of the CBU, the minimum requirement is

- one Radiographer and
- at least one other Authorised or Certified Person.

For **scanning volunteers outside Official Opening Hours** of the CBU the minimum requirement is

- one Radiographer and
- at least two other Authorised or Certified Persons.

For **scanning phantoms** the minimum requirement is one Qualified Operator provided that this person does not enter the Magnet Room. Otherwise, at least one other Authorised or Certified Person must be present.

Volunteer Management

General requirements

1. Approval from the local research ethics committee (LREC) must be obtained prior to the examination.
2. Written MR information that must be made available to all volunteers before their scan as defined in the LREC application.
3. Written informed consent must be obtained before the examination
4. All volunteers must be screened before exposure

Volunteer Management

Insurance cover

Negligent harm: This will be covered by the MRC.

Non-negligent harm: The MRC does not provide cover for non-negligent harm. However it takes a sympathetic view of non-negligent claims.

Abnormal findings

Do not tell the subject!

(This may cause substantial distress and your judgement might be wrong!)

Inform a radiographer or an Authorised Person who will take appropriate action

MR Screening Forms

3.0 T MRI PRE-PROCEDURE SCREENING FORM

MRC Cognition and Brain Sciences Unit
15 Chaucer Road, Cambridge CB2 2EF
Tel: 01223 355 294

Volunteers

Date _____ Principal investigator / Lab _____ Subject ID _____

Name	Last name	First name	M.I.	Height	Weight
Birthdate		Email Address			
Address		City			
State		Zip Code	Phone (H) ()	(W) ()	
GP's name & address					

1. Have you ever had surgery or other invasive procedures? ☐ Yes ☐ No If yes, please list below.
Type: _____ Date: _____
Type: _____ Date: _____
2. Have you had any previous MRI studies? ☐ Yes ☐ No If yes, please list below..

- | Area of Body | Date | Facility Name & Location |
|--|------|--------------------------|
| 3. Have you ever worked as a machinist, metal worker, or in any profession or hobby grinding metal? <input type="checkbox"/> Yes <input type="checkbox"/> No | | |
| or had an injury to the eye involving a metallic object (e.g., metallic slivers, shavings, foreign body)? <input type="checkbox"/> Yes <input type="checkbox"/> No | | |
| 4. Are you pregnant, experiencing a late menstrual period, or having fertility treatments? <input type="checkbox"/> Yes <input type="checkbox"/> No | | |
| 5. Are you currently taking or have recently taken any medication? <input type="checkbox"/> Yes <input type="checkbox"/> No Please list: _____ | | |
| 6. Do you have drug allergies or have you had an allergic reaction? <input type="checkbox"/> Yes <input type="checkbox"/> No Please list: _____ | | |

Some of the following items may be hazardous to your safety or may interfere with the MRI exam. Please check the correct answer for each of the following. If you checked yes, please give more information. E.g. Type of material? How long ago? Use the diagram to indicate where on our body?

- | | |
|--|--|
| <input type="checkbox"/> Yes <input type="checkbox"/> No Cardiac pacemaker | <input type="checkbox"/> Yes <input type="checkbox"/> No Shrapnel, buckshot, or bullets |
| <input type="checkbox"/> Yes <input type="checkbox"/> No IUD or diaphragm | <input type="checkbox"/> Yes <input type="checkbox"/> No Implant held in place by a magnet |
| <input type="checkbox"/> Yes <input type="checkbox"/> No Aneurysm clip or brain clip | <input type="checkbox"/> Yes <input type="checkbox"/> No Shunt (spinal or intraventricular) |
| <input type="checkbox"/> Yes <input type="checkbox"/> No Carotid artery vascular clamp | <input type="checkbox"/> Yes <input type="checkbox"/> No Tattooed eyeliner or eyebrows |
| <input type="checkbox"/> Yes <input type="checkbox"/> No Neurostimulator | <input type="checkbox"/> Yes <input type="checkbox"/> No Transdermal delivery patch (nicoderm) |
| <input type="checkbox"/> Yes <input type="checkbox"/> No Insulin or infusion pump | <input type="checkbox"/> Yes <input type="checkbox"/> No Metal fragments (eye, head, ear, skin) |
| <input type="checkbox"/> Yes <input type="checkbox"/> No Implanted drug infusion device | <input type="checkbox"/> Yes <input type="checkbox"/> No Facelift or other cosmetic surgery |
| <input type="checkbox"/> Yes <input type="checkbox"/> No Spinal fusion stimulator | <input type="checkbox"/> Yes <input type="checkbox"/> No Implanted cardiac defibrillator |
| <input type="checkbox"/> Yes <input type="checkbox"/> No Harrington rods (spinal rod) | <input type="checkbox"/> Yes <input type="checkbox"/> No Cochlear, otologic, or ear implant |
| <input type="checkbox"/> Yes <input type="checkbox"/> No Aortic clips | <input type="checkbox"/> Yes <input type="checkbox"/> No Stents, filters, coils for blocked arteries |
| <input type="checkbox"/> Yes <input type="checkbox"/> No Internal pacing wires | <input type="checkbox"/> Yes <input type="checkbox"/> No Electrodes (on body, head or brain) |
| <input type="checkbox"/> Yes <input type="checkbox"/> No Venous umbrella | <input type="checkbox"/> Yes <input type="checkbox"/> No Wire sutures or surgical staples |
| <input type="checkbox"/> Yes <input type="checkbox"/> No Artificial heart valve/prosthesis | <input type="checkbox"/> Yes <input type="checkbox"/> No Prosthesis (eye/orbital, penile, etc.) |
| <input type="checkbox"/> Yes <input type="checkbox"/> No Artificial limb or joint | <input type="checkbox"/> Yes <input type="checkbox"/> No Metal rods in bones; joint replacements |
| <input type="checkbox"/> Yes <input type="checkbox"/> No Ear tubes | <input type="checkbox"/> Yes <input type="checkbox"/> No Bone/joint pin, screw, nail, wire, plate |
| <input type="checkbox"/> Yes <input type="checkbox"/> No Wig, toupee, or hair implants | <input type="checkbox"/> Yes <input type="checkbox"/> No Asthma or breathing disorders |
| <input type="checkbox"/> Yes <input type="checkbox"/> No Body piercing(s) | <input type="checkbox"/> Yes <input type="checkbox"/> No Seizures or motion disorders |
| <input type="checkbox"/> Yes <input type="checkbox"/> No Metal or wire mesh implants | <input type="checkbox"/> Yes <input type="checkbox"/> No Vascular access port or catheters |
| <input type="checkbox"/> Yes <input type="checkbox"/> No Pessary or bladder ring | <input type="checkbox"/> Yes <input type="checkbox"/> No Other implants in body or head |
| <input type="checkbox"/> Yes <input type="checkbox"/> No Swan-Ganz catheter | <input type="checkbox"/> Yes <input type="checkbox"/> No Hearing aid (Remove before scan) |
| <input type="checkbox"/> Yes <input type="checkbox"/> No Claustrophobia | <input type="checkbox"/> Yes <input type="checkbox"/> No Dentures (Remove before scan) |

Please remove all **metallic objects** before the MR examination including: keys, hair pins, barrettes, jewelry, watch, safety pins, paperclips, money clip, credit cards, coins, pens, belt, metal buttons, pocket knife, & clothing with metal in the material. **Earplugs are required during the MRI examination.**

Your Signature

Date

MR Staff Name

MR Staff Signature

3.0 T MRI PRE-PROCEDURE SCREENING FORM

MRC Cognition and Brain Sciences Unit
15 Chaucer Road, Cambridge CB2 2EF
Tel: 01223 355 294

Staff / Visitors

Date _____ Principal investigator / Lab _____ Subject ID _____

Name	Last name	First name	M.I.	Height	Weight
Birthdate		Email Address			
Address		City			
State		Zip Code	Phone (H) ()	(W) ()	
GP's name & address					

1. Have you ever had surgery or other invasive procedures? ☐ Yes ☐ No If yes, please list below.
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Your Signature

Date

MR Staff Name

MR Staff Signature

MR Screening

Screening From: On arrival in the facility volunteers will be asked to complete the MR Screening Form.

Review of Screening From: A radiographer will then review the screening form with the volunteer.

Preparation for MR examination: A radiographer will then prepare the volunteer for the MR examination. This includes the removal of all unsafe items from the volunteers body/clothes (e.g. watches, credit cards, jewellery, hairpins, body piercings, hearing aids, spectacles, etc). The volunteers will be asked to store these items in one of the lockers provided.

Final check: Before entering the Controlled Area, a radiographer must ensure that the volunteer to be scanned has completed the screening form and that he/she has no unsafe items on him/her. The use of a hand-held metal detector will facilitate this procedure

Part III

Emergency Procedures

Emergency Switches

1. Magnet Quench switch

Used to de-energise (quench) the magnet

2. Power Stop switch

Immediately cuts electrical power to all components of the MRI system
except the magnet.

3. Patient Table Stop button

Immediately stops the motor powered movement of the patient table.

Magnet Quench Switch

Used to de-energise (quench) the magnet

Magnet quench

- The helium coolant boils off abruptly and is released into the open through an exhaust pipe (loud hissing noise).
- Lowering the magnetic field strength to 20 mT takes less than 20 seconds.
- 1000 liters (liquid helium) → 700,000 liters (helium gas)
- The rapid release of the magnet's stored energy is moderately violent, and may cause permanent damage to the magnet.



Control Room

Magnet Quench Switch

Consequences

- Costs about £10,000
- Involves many days of downtime
- May cause permanent damage to the magnet (£500,000)

Magnet Quench Switch

Only use in the event of

- A life-threatening accident
(e.g. a person is trapped between a heavy ferromagnetic object and the magnet)
- An uncontrollable fire in the Magnet Room
which requires the use of ferromagnetic fire-fighting equipment

The decision to quench the magnet should be made by an Authorised Person.

Power Stop Switch

Immediately cuts electrical power to all components of the MRI system. This will not affect the magnet!

Consequences

- You may lose the current scan data
- System recovery may take up to 2 hours

Only use in the event of

- An electricity-based accident
- A fire

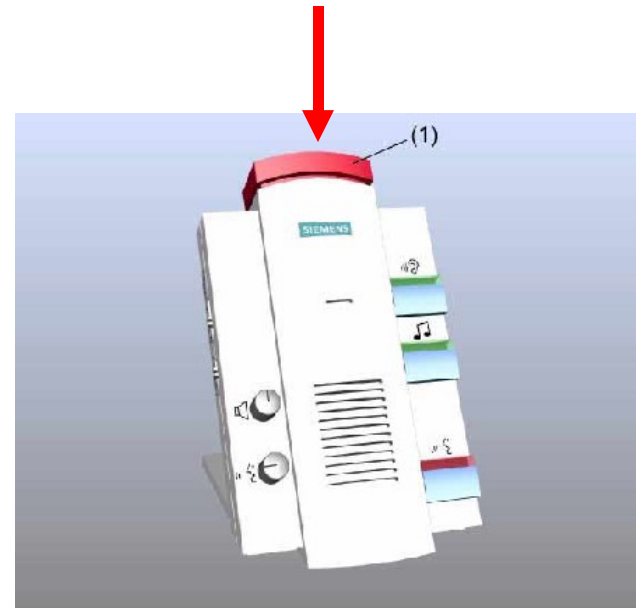
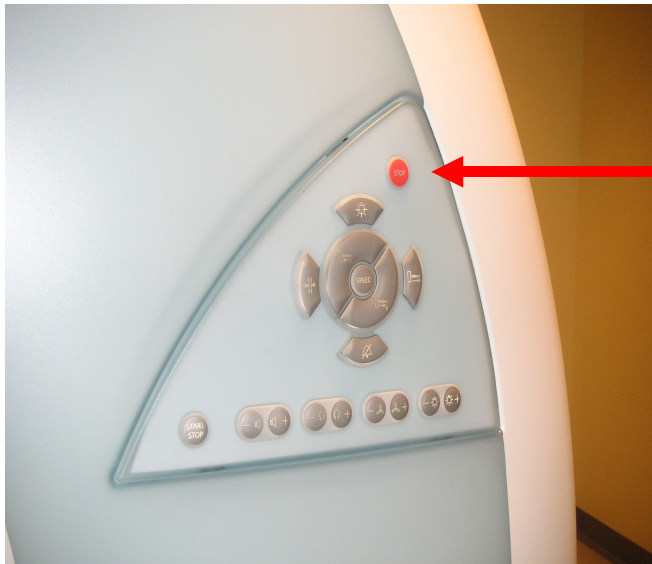


Control Room

Note: The Power Stop Switch does not quench the magnet!

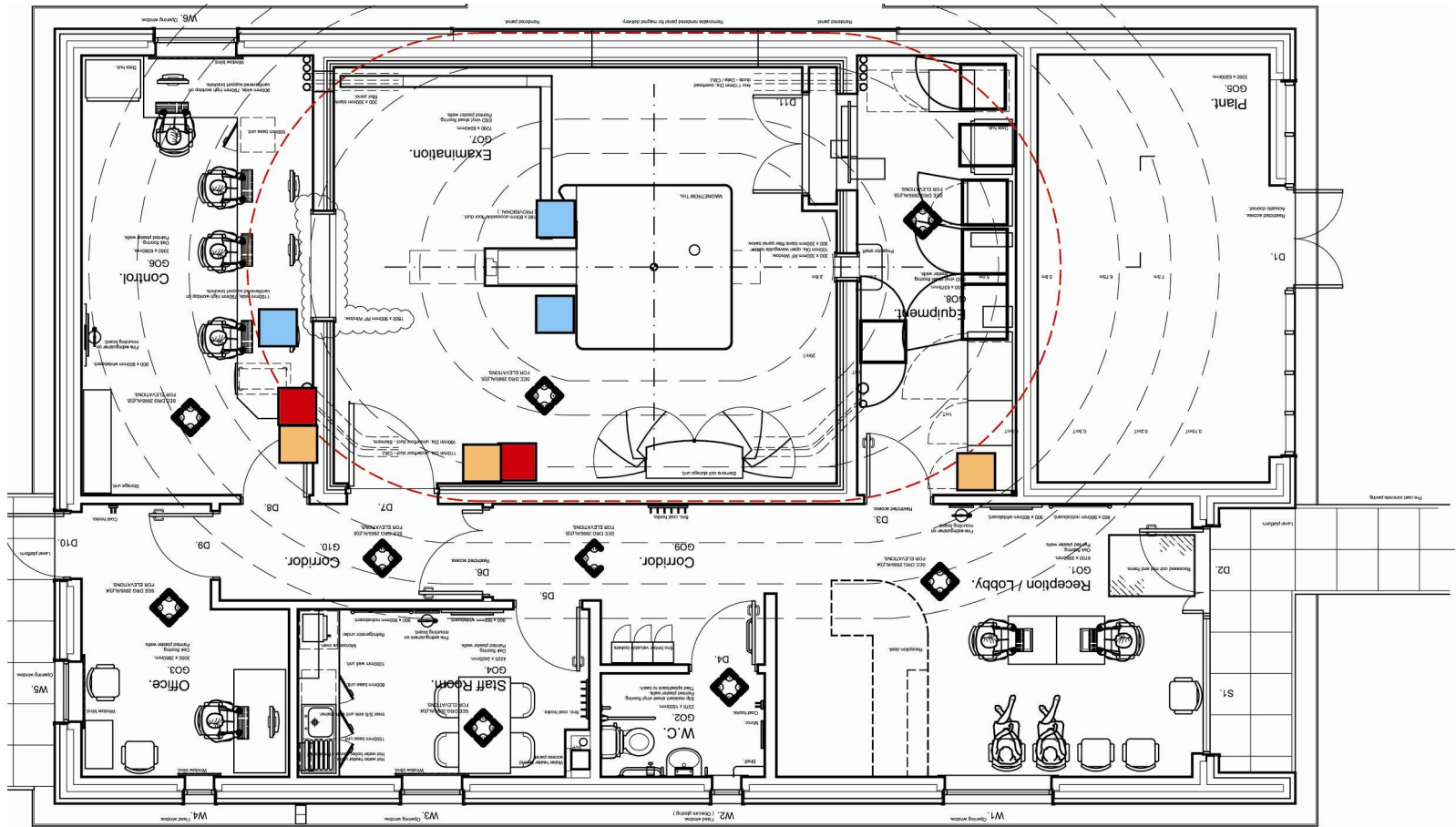
Patient Table Stop Button




Immediately stops the motor-powered movement of the patient table.



Push the Patient Table Stop button in case of accident or risk of injury due to table movements.

Location of Emergency Switches



-  Magnet Quench
-  Power Stop
-  Patient Table Stop

Emergency Procedures

1. Medical emergency (cardiac arrest)
2. Fire
3. Magnet quench

Medical Emergency

Person A

- Call 888 to summon CBU first aiders to the Imaging Facility
- Call 9 999 for an emergency ambulance
- Report our location
Imaging Facility
MRC Cognition and Brain Sciences Unit
15 Chaucer Road, Cambridge, CB2 2EF
Emergency Telephone 01223 273747
Switchboard must repeat this back to you!
- Report what has happened
Details of the medical emergency (e.g. suspected cardiac arrest)
- A person should be sent to the front car park to direct an ambulance where to go
- Inform CBU reception on 100 (only during normal working hours)

Person B

- Terminate scan
- Remove patient from bore of the magnet bore

Together

- Remove patient from the Magnet Room using the plastic carry sheet if needed.
- In case of cardiac arrest: Start cardiac massage and resuscitation immediately!
(15 cardiac compressions: 2 breaths - 2 persons)

Fire

- Raise the fire alarm
- Call 9 999 for emergency services

Report our location

Imaging Facility

MRC Cognition and Brain Sciences Unit

15 Chaucer Road, Cambridge, CB2 2EF

Emergency Telephone: 01223 273747

Switchboard must repeat this back to you!

Report details about the fire:

How big? In which rooms? Fire in the Magnet Room?

In case of a medical emergency

(follow Medical Emergency Procedures)

- Terminate all MR procedures
- Press the Power Stop button
- Evacuate the MR Unit, collecting the AED and first aid equipment on route if safe to do so.
- Do not enter until the system has been declared safe by a suitably qualified person

Fire in the Magnet Room


- Use only fire extinguishers clearly marked as MR Safe (non-ferromagnetic)
- If ferromagnetic fire-fighting equipment needs to be brought into the Magnet Room, the magnet must be quenched.

Magnet Quench

A quench may be triggered

- By pressing the Magnet Quench switch
- If the Helium level in the magnet falls too low (<35%)
- By an accident (earthquake, fire, etc.)

During a magnet quench

- the liquid helium in the cryostat boils off rapidly and is released into the open through an exhaust pipe.
- 1000 liters (liquid helium) 70  000 liters (helium gas)

Magnet Quench

Hazards

- In case of a leaking exhaust pipe, large amounts of cold helium gas may accumulate in the Magnet Room and displace the oxygen there.
- **Danger of frostbite and asphyxiation.**
- Oxygen sensors in the magnet room will trigger an alarm if oxygen level drops below a critical level.



Oxygen alarm unit in the Control Room

Danger of death by asphyxiation! Do not enter the magnet room if the oxygen alarm is on!

Magnet Quench

Rescue

- Terminate the scan
- If possible, rescue patient/volunteer immediately

Evacuate

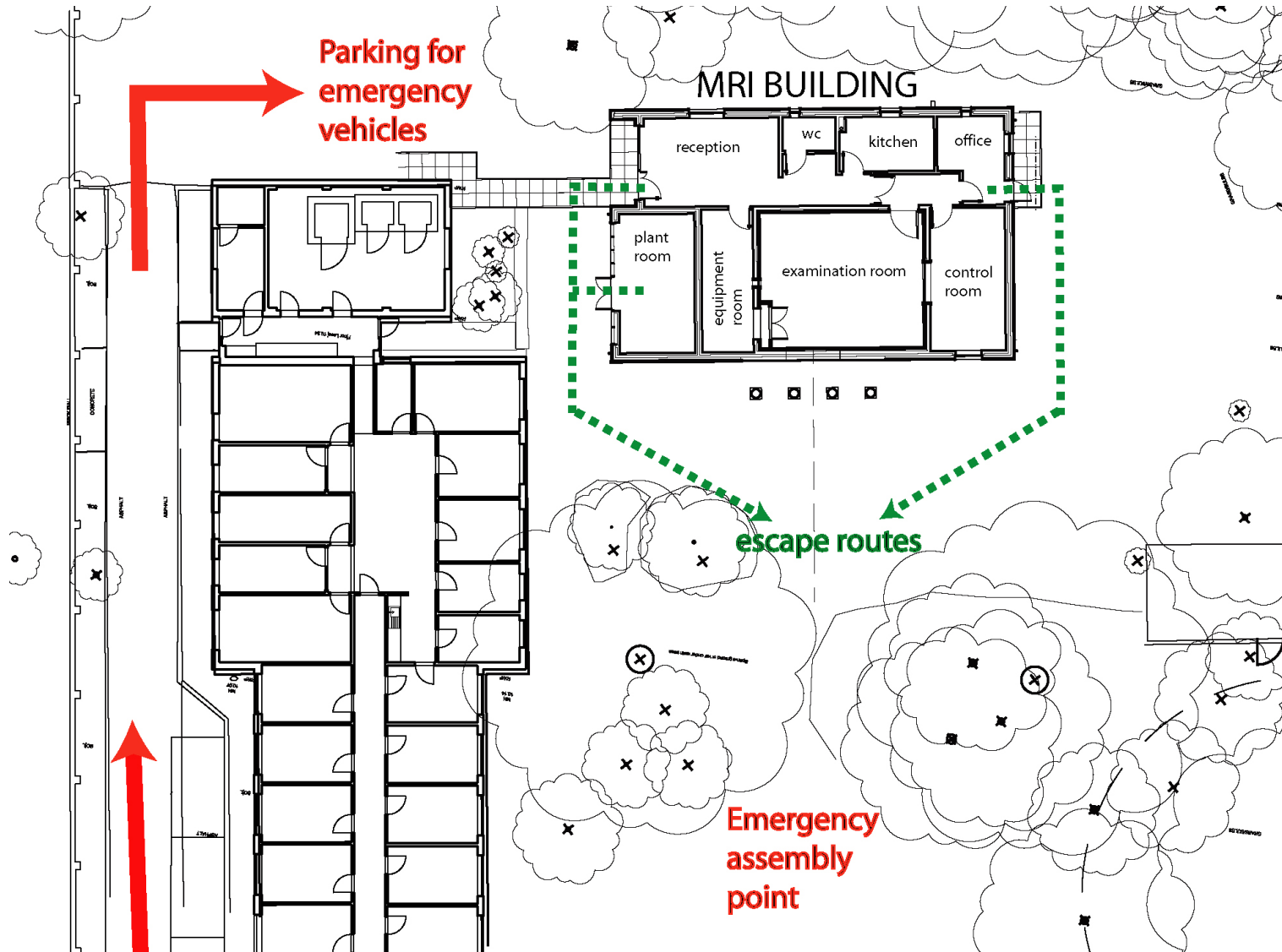
- Evacuate the MR Unit (sound the fire alarm)
- Do not enter until the system has been declared safe by a suitably qualified person

In case of a medical emergency

(follow Medical Emergency Procedures)

Danger of death by asphyxiation! Do not enter the magnet room if the oxygen alarm is on!

Escape and Evacuation Routes



MR Safety Quiz