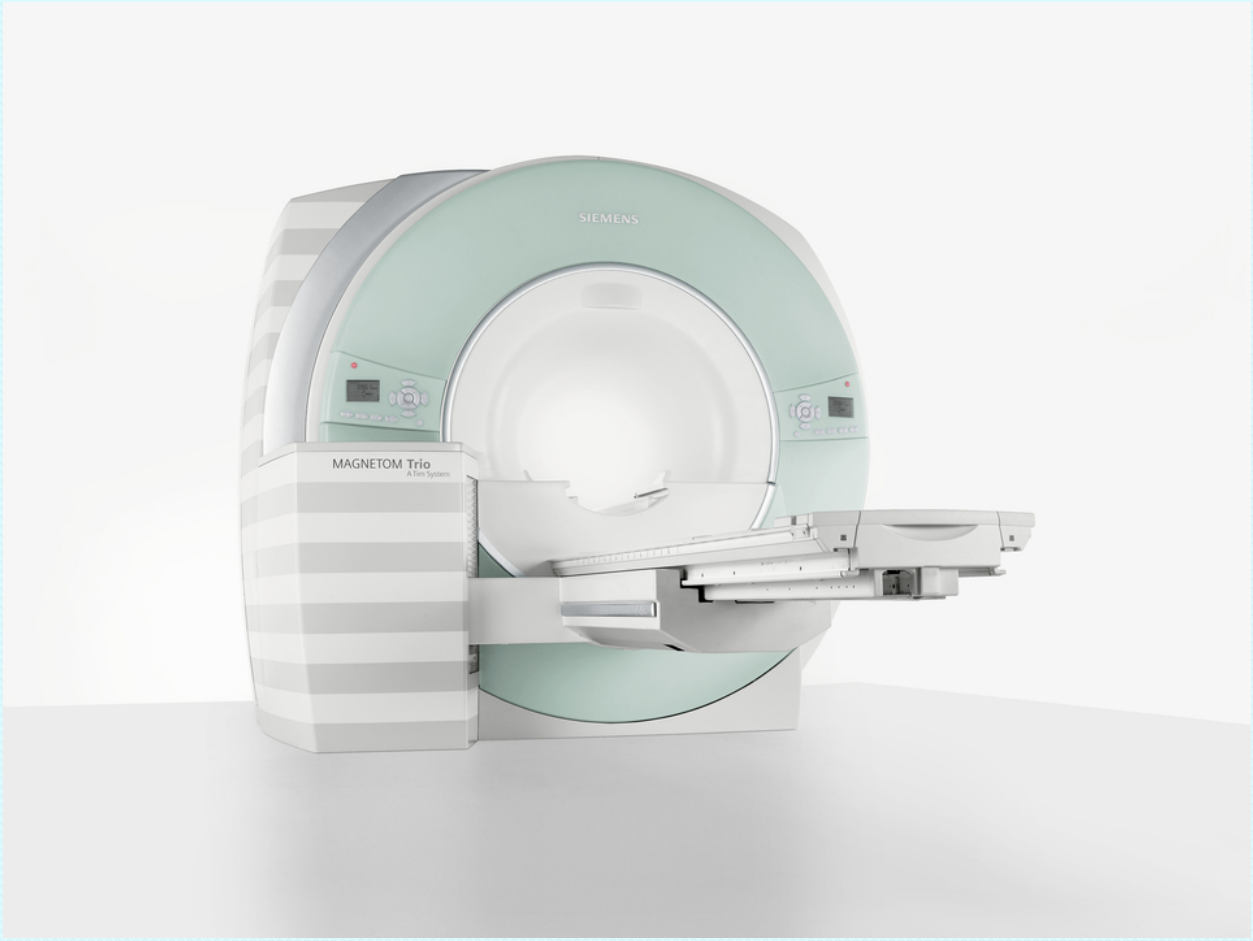
MRI Safety And Good Behavior Training

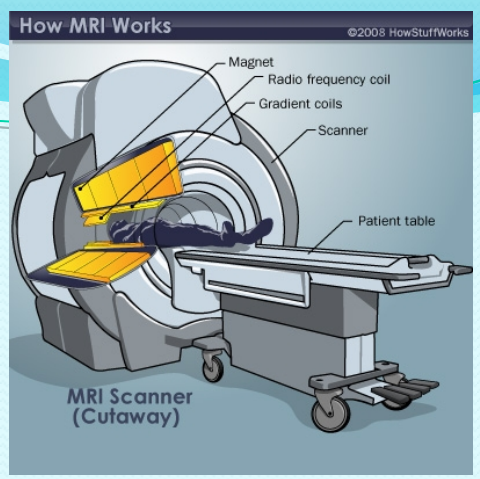


MRI SAFETY

Magnetic Resonance Imaging (MRI) is one of the most powerful medical diagnostic technologies, combining strong magnetic fields with powerful computer image processing.

In the context of research, there is no direct benefit to MRIs. Thus, some policies are more stringent than for clinical. You must be aware of such differences.

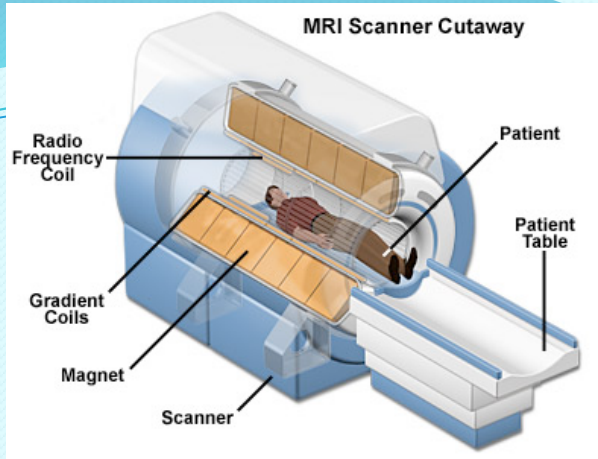
The MR Scanner



- MR scanners produces images by "tipping" hydrogen atoms. The scanner uses radio waves to tip the atoms. When the atoms are tipped, they spin because of the large magnet, and the coils in the MRI scanner can detect these spinning atoms. Because the human body has so much water, most of this signal comes from the hydrogen atoms in water. The way that they spin and how long they spin changes based on the local environment of the atoms (such as whether they are in fluid or solid tissue, or whether there is nearby oxygenated blood). Different image types are sensitive to different aspects of the environment of the hydrogen atoms. In order to tell where these hydrogen atoms come from, the scanner only tips hydrogen atoms from a small part of the scanner at a time. The process of selecting which atoms get tipped uses gradient magnet fields. These are much smaller than the main magnet, but change quickly during the scan.

- To make these images, the scanner needs three main parts:
- The main (large) static magnetic field
- Radio frequency coils to tip the hydrogen atoms and detect their spinning
- Gradient coil

THE MR SCANNER



Static Field: The core of an MRI machine is a very large and powerful magnet arranged to surround most of the patient's body. In most clinical scanners, this is 1.5 – 3 Tesla. One Tesla is 10,000 Gauss, and the Earth's magnetic field is ~0.5 Gauss. At the Jamaica Plain Campus, we have a 3T scanner.

This magnet is usually produced with super-cooled copper wire, and when electricity flows through the wire a powerful magnetic field is produced. When you walk into the MRI scanner, you can hear the pumping of the cryogens that keep the copper wire super-cooled.

Superconducting wires continually conduct electric current without resistance, and it takes a long time to get them that cold without damaging the wires. Because of this **the magnetic field is present 24 hours a day; whether the MRI machine is being used or not.**

Gradient Field: During image acquisition, smaller magnetic fields are turned on and off so that the magnetic field across the bore of the magnet is different. These are much smaller than the main magnet field, and are not on when the scanner is not taking an image. However, because these gradients switch on and off quickly, they can induce electrical currents in objects and tissue within the scanner. Many objects will heat up when current flows through them. These currents can also cause stimulation of nerves (producing twitching or tingling feelings that are generally harmless), but only at high strengths which are generally not used for normal imaging.

Magnetic Fields

- Static (larger) magnetic field represents the constant magnetic force of the magnet.
- Gradient (smaller) magnetic fields are produced by the various coils during the MR procedures according to the sequence of acquisition selected.
- Static fields are responsible for the projectile effect while the gradient fields are responsible for current generation.

Before Scanning

- Screening participants ahead of time is mandatory.
- Because the magnet may affect metallic implants, tattoos, shrapnel, etc., a comprehensive review of your participant's medical history is essential.
- This interview should cover not just the past 2 months, but all surgeries. If the participant has implants, make sure to obtain the make and the model of the implants so that the MR technician can verify their safety. There is no time limit for implants: document them all!

Before scanning

- The MRI screening form is available on the VA Boston Imaging wiki.
- This should be completed by the participant with the help of the research staff. The screening form should be reviewed by the MR technician before the scan.
- Every year, medical supplies manufacturers release a list of products tested for MRI at 1.5 and 3 Tesla. Not every product safe at 1.5 is safe at 3 T. A list of safe products is available at the scanner.

Potential Value of Ferromagnetic Detectors in MRI Screening

Issues

- Over-dependence by users
- Detects external metal, not internal
- Generates false-positive & false-negatives
- Function dependent on many variables
  - Motion rate of detector relative to metal
  - Size & mass of metallic object
  - Sensitivity setting of detector

Magnet Room Acceptability Labels

MR SAFE- Green
an item which poses no known hazards in all MR environments

MR UNSAFE- Red
an item which is known to pose hazards in all MR environments.
MHRA DB2007(03) December 2007

MR CONDITIONAL- Yellow
An item which has been demonstrated to pose no known hazards in a specified MR environment with specified conditions of use. Field conditions that define the specified MR environment include field strength, spatial gradient, dB/dt (time rate of change of the magnetic field), radio frequency (RF) fields, and specific absorption rate (SAR). Additional conditions, including specific configurations of the item, may be required.

In sum, if in doubt…

- There are official resources where you can find out the safety of specific objects.
- The MRI technicians of the JP campus are there to help but need time to process inquiries.
- Try to obtain the original reports from any surgery, including the surgeon's and nurse's operative reports, including the make and model of all implants.

At the Scanner

- The MRI environment is divided into 4 zones
  - Zone 1: Outside the MRI suite
  - Zone 2: the Reception Area / screening area
  - Zone 3: The console room where the technician operates the scanner from; access restricted with key locks, passkey systems etc.
  - Zone 4: The Magnet room (where the scanner is located)

  - Non-MR personnel should never be allowed into zones 3 or 4 without the express consent and supervision of the MR technician.

Importance of the Zones

- Screening forms should be reviewed in Zone 2
- Individuals accompanying the participant should wait in Zone 2
- Only trained individuals should have access to Zones 3 and 4.
- Metal objects should never enter Zone 4.
- In case of emergency (e.g. fire or medical emergency), emergency personnel should not be allowed into zones 3 or 4 because they are not trained.

The risks of the magnetic fields

- The Projectile Effect
- The Torsion
- Gradient-Induced Current
- Pregnancy policy
- Acoustic Noise
- Tattoos, Piercings and Permanent Cosmetics
- In case of emergency
- Also, remember that research studies present no benefits for the participants. Therefore, all risks should be at a minimum.

Remember, the magnet is ALWAYS on!

Even when the MRI Scanner is not in use, the magnet is on and at full power. Ferromagnetic objects should NEVER be taken into the Scan Room.

The projectile effect

- The magnet is powerful enough to attract metallic objects, in a straight line, towards where the magnetic field is strongest. If you are doing a head scan, that would be where the head of your participant is. This has caused injuries and deaths in the past.
- No metallic object should enter Zone 4. This is why there is a metal detector at the door. The door represents the last safe distance. Even a few steps inside the room can attract an otherwise stable object at speeds up to 40mph.

Potential Projectiles: Examples

- **Cell phone**
- **Keys**
- **Glasses**
- **Hair pins / barrettes**
- **Jewelry**
- **Safety pins**
- **Paper clips**
- **Coins**
- **Pens**
- **Pocket knife**
- **Nail clippers**
- **Steel-toed boots / shoes**
- **Tools**
- **Clipboards**
- **No loose metallic objects should be taken into the Scan room (Zone 4)!**

As an exercise

- Stop here and review all metallic elements on you right now. What would you need to take off, take out of your pockets, etc?

Torsion

- Even if a metallic object is unable to translate closer to where the magnetic field is strongest, it might realign itself to the axis of the magnetic field.

- This torsion is especially true for implants that may twist and turn inside a participant's body, causing tissue damage and bleeding.

Gradient-induced Current

- The alternating gradient magnetic field can induce some electrical current in tissues.
- At low levels, these currents may induce a tingling sensation in peripheral nerves. This sensation is normal.
- At higher levels, this current can create a burning sensation, leading to actual second degree burns, if it finds a loop. To prevent this, instruct participants to avoid crossing their arms, legs or fingers.

Effects on DNA and Pregnancy

- There's no evidence indicating biological side effects from the magnetic fields of an MRI scan, and MRI machines don't utilize any ionizing radiation that can damage cells or DNA.

- While there is no clear evidence of the effect of MRI on pregnancy, since there is no direct benefit to scanning for research, female participants should be scanned only if they are not pregnant. If in doubt, reschedule the participant until you are sure she is not pregnant.

Acoustic Noise

- When the alternating low-frequency currents flow through the gradient coils, which are immersed in the high static magnetic field , forces are exerted on the gradient coils that move like a loudspeaker coil and generate sound waves. The level of this acoustic noise at the location of the subject or volunteer can reach an unacceptable and even dangerous level (usually greater than 95db, whereas permanent hearing damage can occur with sounds at 85db).
- All personnel (MRI Technician, research group member, volunteer subject, family member, etc.) are required to wear hearing protection in the magnet room while the scanning procedure is being performed.

Tattoos, Permanent Cosmetics and Piercings

- Most tattoos done in the US are safe and contain no ferromagnetic metals. Tattoos not done by professionals in the US may contain metallic traces. Red ink is a particular risk.
- In some cases, tattoos and permanent cosmetics may heat up and lead to first and second degree burns. While these are rare effects, they should be carefully considered, screened for and monitored by research staff (i.e. included on the screening form and mentioned to the participant).
- Even if a piercing is not located on the area to be imaged, it should still be removed. Even non-ferromagnetic metals represent a risk because of the gradient-induced current.

In case of emergency

- Call 911 (scans are done after hours, thus require direct call to 911)
- Remove the participant to zone 2
- Start CPR if necessary
- Make sure that the door to the magnet room is locked and that no unauthorized personnel enters the magnet room (e.g. police officers and firemen)

Quenching the magnet

- The magnet is supraconductive because it is bathed in liquid helium. If the magnet loses its temperature (~5 degrees Kelvin), it loses its potency.

- A quench is the rapid boil of the cryogen, usually helium, and ultimate loss of magnetic field.

- The helium will expand from liquid to gas form. This massive expansion (1 lb to 1 gallon, or 1 kg to 8 L) is evacuated by vents outside the magnet room.

Quenching con't

- Quenching the magnet may be dangerous and should not be attempted unless necessary.
- The door to the magnet room should be open during the quench, to allow the continued flow of air.
- If there is a problem with the vents, and if the door to the magnet room cannot be opened, the window from the console room should be broken.

The End

- If you have any questions, feel free to contact the MRI technicians.
- Remember that it is your responsibility to insure your participant's safety.
- And remember this: you may forget the magnet, but the magnet is always on and never forgets!

Rules of behavior: before scanning

- Assess eligibility of participants as early as possible before booking a scan slot.
- Document surgeries, tattoos and other possible exclusion criteria for the scanner ahead of time. If in doubt, please allow the technicians time to review a case and conduct the appropriate review of implants or other medical devices.
- On the day of scanning, use the screening (clearance) form provided on the wiki. Make sure all fields are properly filled for the technician to review with the participant.

Rules of behavior: Canceling a scan

- When canceling a scan send an email to:

vabostonimagingusers@googlegroups.com

to let people know that the slot is released.

- Cancel the event on the calendar.
- Send an email to jessesayers@gmail.com the the title "Scan Slot Released", with the time canceled and a brief explanation of why there was a cancelation (i.e. participant is sick.)

Rules of behavior: at the scanner

- Make sure you confirm your presence at the scanner by phone (#42896) ahead of time.
- Arrive at the MRI suite in advance. Direct your participant to the waiting (seating) area until the technician is ready to review the clearance form.
- Provide ample time for your participant to review the clearance form with the technician (if there are issues, plan for extra time), change into MRI safe clothes, and use the restrooms.

Rules of behavior: at and after the scan

- You are responsible for providing all the documents needed for clearance.
- You are responsible for providing all information to the participant about what they need to do during the scan.
- You are responsible for knowing the parameters of your specific scans
- You are responsible for escorting the participant to the Zone 4 door before the scan, and out of the MRI department after the scan.