How to Learn MRI

An Illustrated Workbook

Exercise 2a: Tour of the MRI Scanner Including All Emergency Features

Exercise 2b: Patient Safety Screening

Teaching Points:

- How to determine if your volunteer is safe for MRI scanner.
- How to operate MR scanner mechanicals.

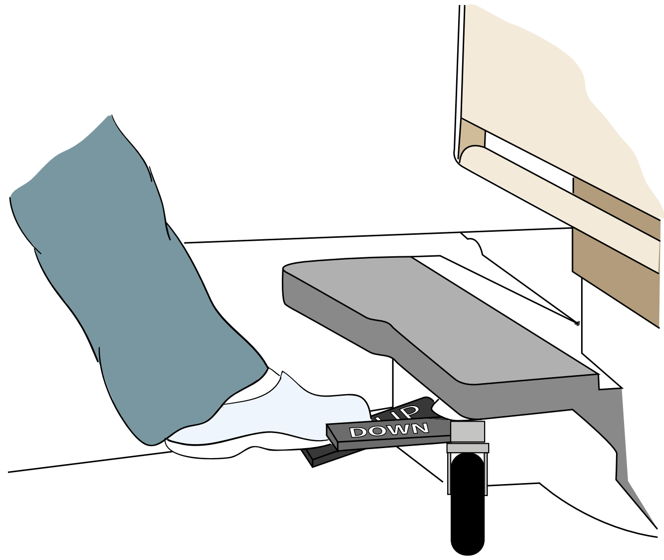


Fig 2.1 Stepping on the pedal

EXERCISE 2a: Tour of the MRI scanner including all emergency features

STEP 1: Safety

We assume you already know what to remove from your pockets.

STEP 2: Stepping on the Pedals

a) Step on the pedals on the side of the table. Identify which one raises the table and which one lowers the table. Wow that raising of the table makes a lot of noise! Maybe I'll do it manually next time to avoid scaring the patient. Manual raising is at the end of the table away from the scanner.

b) There are four pedals with labels on it located in front of the mobile transport. Try to step on each pedal and see if it really performs its function.

c) Pull the red emergency release lever at the right side, below the table, just above the up/down pedals. Observe what happens. It is used to manually release the patient transport from the docking mechanism.

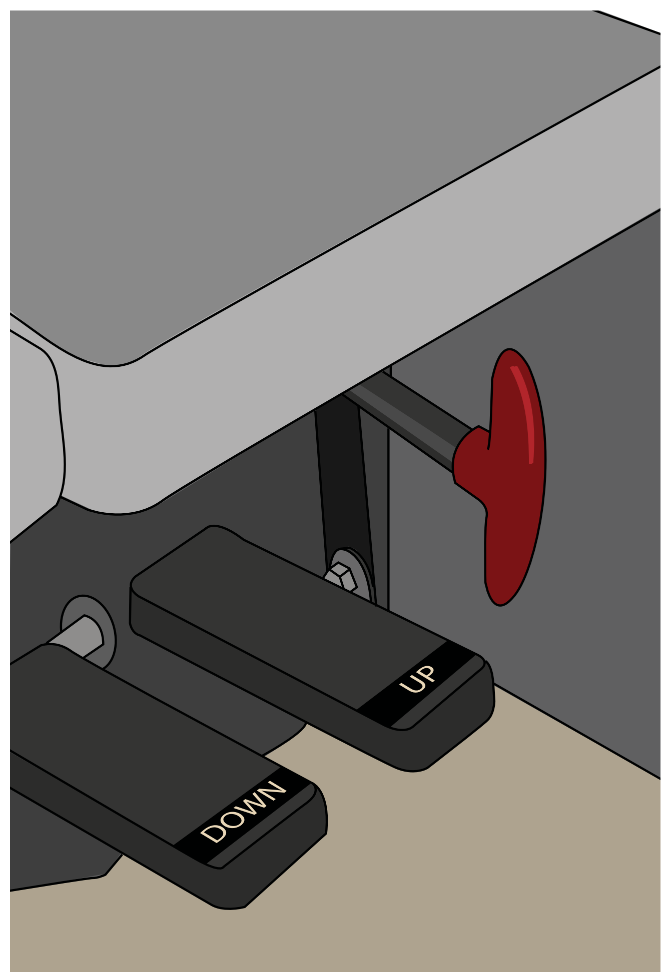


Fig 2.2 Emergency Release Lever

STEP 3: Pushing the Buttons

Place the phantom on the scanner table.

a) Turn on the alignment light by pressing on button labeled **"Align On".**

b) Adjust the table until the light hits on the phantom landmark. To push the cradle in, press the button labeled **"In Slow"** button and then the button labeled **"In Fast"**.

To push the cradle out, press the button labeled **"Out Slow"**, followed by the button labeled **"Out Fast"**.

c) To Landmark, press the button labeled **"Landmark"**. Note that the S/I position indicator reads zero.

d) To position the phantom to be scanned, press advance to scan. **"Advance to Scan"**.

e) To immediately stop the cradle, press the **"Stop Table"** button.

f) If an emergency happens in the scan room, press **"Emergency Stop"**. This will stop the scan AND SHUT OFF POWER TO THE MAGNET AND ALL ELECTRONICS IN THE SCAN ROOM, you then have to reset the scanner to get the magnet working again.

g) If you should need to stop the scan press **"Pause Scan"**, or **"Stop Scan"**. These buttons stop the scanner, and you can then reset the sequence or change parameters.

h) If you want to scan again, you can press the button labeled **"Back to landmark"** before pressing the **"Scan"** button in the console room.

i) Press the button labeled **"Light On"** to turn on the light, especially if the patient is claustrophobic.

j) Press the button labeled **"Fan On"** to control circulation of air within the magnet opening also to reduce claustrophobia.

k) To fully bring the cradle out, press the button labeled **"Home"**.

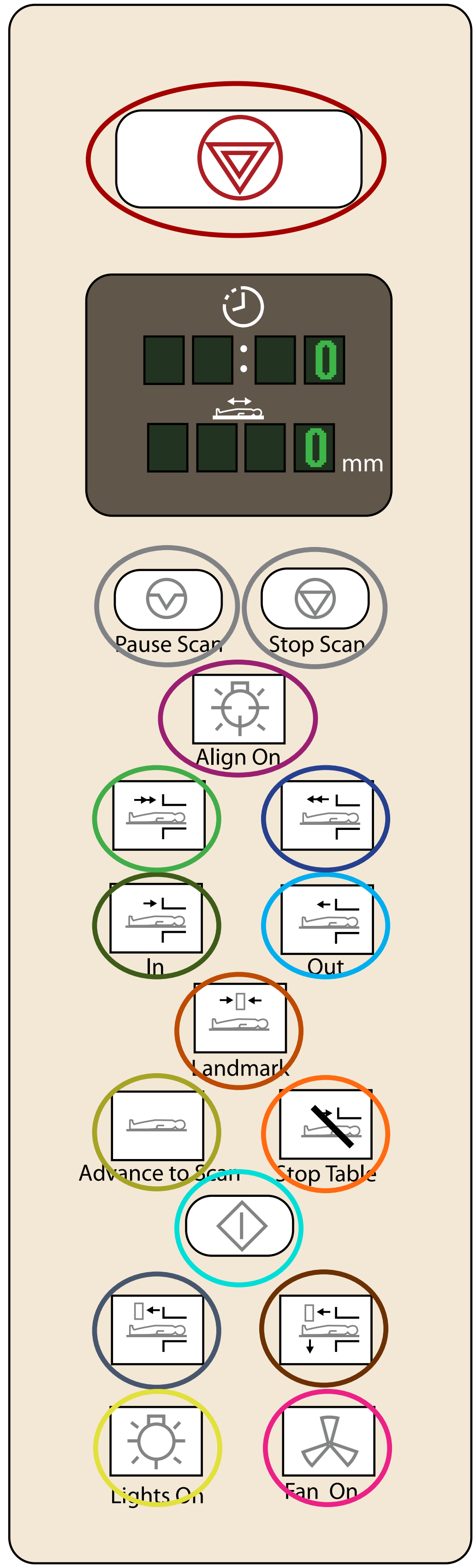


Fig 2.3 Button Controls

STEP 4: Learning the PAC UNIT (Physiologic Acquisition Controller)

Get a volunteer and do the following:

a) Place the respiratory compensation bellows around the abdomen of your volunteer. The bellows are permanetly attached to a port on the PAC unit. Observe the respiratory signal return and strength at the bar graph LED. This should illuminate at least half or better of the bar graph LED.

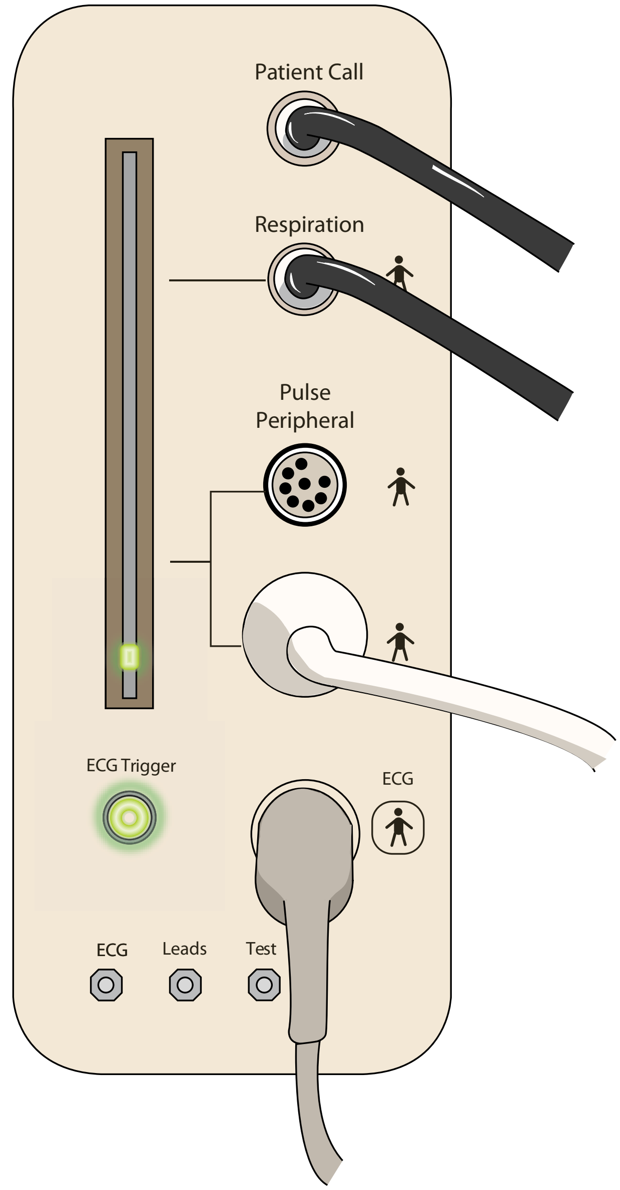
b) Place the peripheral gating lead to the volunteer's finger and connect to the corresponding port on the PAC unit. Observe the signal return and strength of the peripheral gating lead on the bar graph LED, which should illuminate at least half or better of the bar graph LED.

c) Place the disposable ECG leads on the volunteer's chest and attach them to the corresponding clips coming out of the ECG port on the PAC unit (see figure 2.4). Note that in MRI ECG leads are placed closer together then a normal ECG. This is to reduce the interference of the RF and Electrical signal from the magnet in the ECG signal.

Observe the ECG signal return at the ECG trigger LED. Go into the console room and see on the monitor if the ECG is working. The ECG configuration in figure 2.5 is just one of many that can be used. Try out some different configurations and check which one gives you the best signal on the computer in the console room.

d) Instruct the volunteer to squeeze the bulb and see if it creates a sound and a light on the control box near the operator workstation desk.

Fig 2.4 The PAC Unit



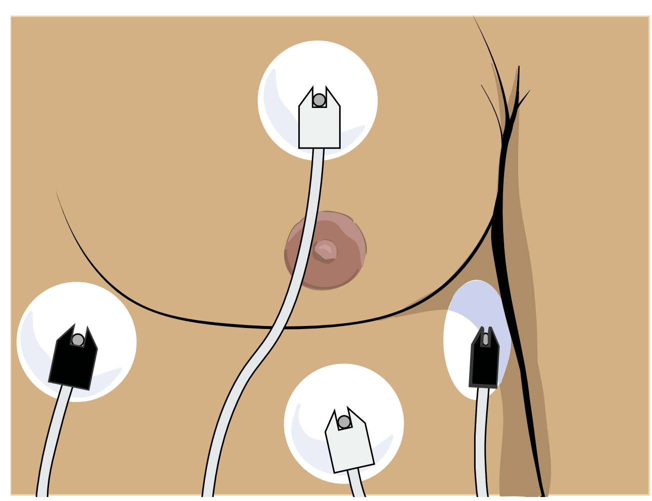


Fig 2.5 Patients Chest

Why do you need a magnetic field?

A proton has a positive electrical charge and has a spin, which is constantly moving. The electrical charge also moves, which is an electrical current. The proton has its own magnetic field. Protons are normally arranged in a random fashion. When they are exposed to an external magnetic field, they aligned themselves in two ways, either parallel (pointing up) or anti-parallel (pointing down) to the external magnetic field. Both alignments have two different energy levels. The lower energy level is the preferred state. Thus, more protons are parallel to the external magnetic field.

Movement of protons is called precession. The type of movement is best presented by a spinning top, which when hit, starts wobbling or tumbling around. A cone shape is formed by the spinning top circles. Speed of the protons can be measured using the precession frequency. It measures how many times the protons precess per second. This is dependent on the strength of the magnetic field and is directly related. The stronger the magnetic field, the higher is the precession frequency and the faster the precession rate.

The Larmor equation is the equation used to calculated the frequency. It is $w_0 = \gamma B_0$, where in w_0 is the precession frequency in Hz or Mhz, B_0 is the strength of the externalmagnetic field in Tesla (T) and g is called the gyromagnetic ratio. The gyromagnetic ratio of a hydrogen proton is somewhere around 42 Mhz/T in magnetic field strength of 1.5 Tesla.

The coordinate system represents the proton motion in the magnetic field. As we all know, a vector is anything with magnitude and direction. The magnitude is the magnetic force. Magnetic forces in the opposing directions cancel each other out, thus there are more protons pointing up than down. The resulting vector is the sum of all the magnetic forces. In correlation to the MR unit, putting the patient inside makes himself a magnet with his own magnetic field, due to the vectors of the protons that add up.

Longitudinal magnetization is the magnetization along or longitudinal to the external magnetic field. The new magnetic vector is aligned with the external magnetic field, pointing up. This is actually used to get the signal. However, magnetization along an external magnetic field cannot be measured. Transversal magnetization is necessary in this case.

When we put the patient into the magnet, an electromagnetic radio-wave is sent in. These waves are short bursts of some electromagnetic wave and are called the radio frequency (RF) pulse. An RF pulse disturbs the alignment of the protons that is only possible if there's an exchange of energy. Protons can pick up some energy from the radio-wave only when the RF pulse and the protons possess the same frequency. This phenomenon is called resonance. Less energy or no energy transfer occurs in those with differences in speed/frequency.

Sending in an RF pulse that has the same frequency as the precession frequency of the proton has two effects: some protons pick up energy and this causes the protons to precess in step, in phase. The vectors add up and point to the same direction at the same time. The former decreases the amount of longitudinal magnetization and the latter creates a new magnetization moving around the precessing protons, called transversal magnetizatiozn. Transversal magnetization possesses a procession frequency and thus moves in line with the precessing protons. The constantly moving and changing magnetic vector induces an electric current. An electrical current induces the magnetic field and vice versa.

Design of a Magnet

Field strength of a magnet used for imaging is between 0.5 to 3 Tesla. 1 Tesla is equivalent to 10000 Gauss. Magnets are the most important part of the MR machine. It is important for the magnetic field to be homogenous because it determines the precession frequency. This is described in ppm or part per million, where it is the difference between maximum and minimum field strength divided by the average field strength multiplied by one million. Homogeneity can be improved by the process of shimming or making some electrical and mechanical adjustments.

There are different types of magnets. One is the permanent magnet which does not use energy, but it has a limited field strength, unstable thermal energy and its very heavy. Another type is a resistive magnet which has an electrical current that flows through them, thus making it magnetic. These are also known as electromagnets and can become warm during operation due to the resistance to the flow of the electricity through the wire, so they need to be cooled. They have a higher field strength, but this can be impractical because they produce lots of heat that must be dissipated. A new iron core (hybrid) resistive magnet was invented combining the features of permanent and normal resistive magnets. The last type of magnets are the superconducting magnets. They use a special current carrying conductor, which is cooled down to superconducting temperature which is around -269 degrees Celsius (absolute zero). The current conducting material loses its resistance for electricity at this temperature. Cryogens (helium, nitrogen) are used to cool these magnets. Sudden resistance to the flow of electricity and preventing the temperature from reaching quench, which occurs when the temperature increases above the superconducting temperature, is important to prevent rapid heat production which can cause the cryogens to boil off rapidly, called the quench lines. Superconducting magnets have high magnetic field strength and good magnetic field homogeneity that gives better spatial resolution, but they are very expensive.

What is a coil?

Coils are used to either transmit the RF pulse to excite the protons, receive the resulting signal, or do both. There are different types of coils:

- Volume coils surround the patient, especially the part of the body that has to be imaged. It receives the signal when larger parts of the body are examined.
- Shim coils are used for electrical and mechanical adjustments to compensate for inhomogeneities and imperfections in the main magnetic field. The process for this is called shimming.
- Gradient coils make it possible for slice selection and spatial information to occur because they produce additional linear electromagnetic fields. These are three sets of wire coils wrapped around a fiberglass cylinder within the magnet housing, which causes noise because they bang against their anchoring devices.
- Surface coils are receiver coils, placed on the part to be examined. They are not used for deeper structures, they are only used to receive signals from nearby structures. They vary in shape depending on the area of interest.

The Faraday Cage

The Faraday cage is used to shield the MR system and prevents outside radio-wave interference. Since different external factors can influence the homogeneity of the magnetic field, it is important to reduce external signals. The MR magnet room is setup to be a large Faraday cage. Closing the door to the magnet room is necessary to complete the cage and thus reduces external interference.

Exercise 2b: Patient Safety Screening

Answer the Patient Screening form 1 and 2 below to see for yourself if you are MRI compatible.

Weil Cornell Imaging at New York- Presbyterian

MRI is simple, safe and painless. However, because we use strong magnets during the procedures, metal objects in your body may be hazardous or cause interference. Please provide us with this important information before entering the MRI department

Name____ Age_________ Weight________

Referring Physician____

Have you ever been here before and when________________________________
Have you ever had an MRI? Yes________No__________ Date and Place of MRI________________________

List other imaging related to todays examination with date and location (Cat scans, Ultrasound, X-Ray)

____

Have you ever had surgery Yes_________ No_________ If yes, please list all procedures and dates

____

____

Do you have any of the following

Tumor	Yes_______	No_______	Location________________
Cancer	Yes_______	No_______	________________
High Blood Pressure	Yes_______	No_______	Year Diagnosed___________
Stroke	Yes_______	No_______	

Do you have any of the following items in your body?

Pacemaker	Yes_______	No_______	ImplantedElectrical Device	Yes_______	No_______
Ear/Cochlear Implant	Yes_______	No_______	Neurostimulators	Yes_______	No_______
Brain/Aneurysm clips	Yes_______	No_______	Metal Fragments/Shrapnel	Yes_______	No_______
Tissue Expander	Yes_______	No_______	Stents	Yes_______	No_______
Metal in Eyes	Yes_______	No_______			

Any other metal objects or implats ____

____

If known please give name and date of implant ________________________________

Are you on Dialysis?	Yes_______	No_______
Do you have a history of Kidney or Renal Disease?	Yes_______	No_______

Have you ever had an injection of contrast for an MRI? Yes_______ No_______
(MRI contrast is not the same as CAT scan contrast)
If yes did you experience any of the following

Hives	Yes_______	No_______
Shortness o breath	Yes_______	No_______
Fainting or Collapse	Yes_______	No_______

FEMALE PATIENTS

Is there any possibility or Pregnancy?	Yes_______	No_______
Are you Breast Feeding?	Yes_______	No_______

Fig 2.6 Patient Screening Form: Part 1

Weil Cornell Imaging at New York- Presbyterian

Please describe in detail why your doctor has requested an MRI or MRA?

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____
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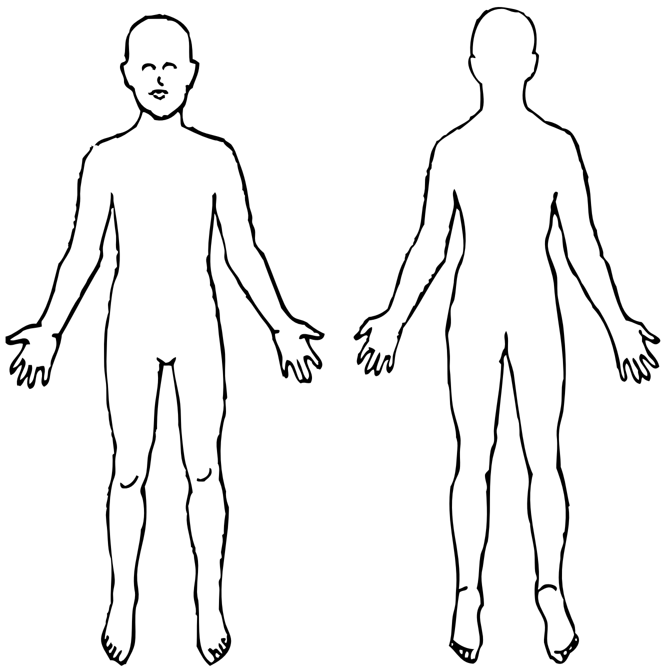
Please indicate your symptoms in the diagram



Sometimes MRI requires an injection of contrast. MRI contrast (Gadolinium) is administered through a small needle placed into a vein. During the administration of MRI contrast, you may experience the sensation of the contrast being Injected, which is normal

MRI contrast (Gadolinium) is quite safe, however as with all medications, there is a slight risk of an allergic reaction. The physician and staff in the MRI department are trained to respond to any emergency situation that may develop. In addition, we use the safest MRI contrast, which our physicians believe is best for you. Gadolinium has no animal or food products or derivatives, sodium chloride, glucose or preservatives.

Literature on the Magnevist Gadolinium is available at the front desk

I have read and understand the above information

Signature____Date________________

Fig 2.7 Patient Screening Form: Part 2

MRI Safety

Do you have ferromagnetic devices inside you? These metal objects get pulled into the magnet bore; potential hazard can be produced to the patient or anybody working in the MRI unit. Stronger forces are involved in bigger objects and can be very dangerous and deadly. There will be great twisting of force in order to align its long axis with the static magnetic field lines of force. This is called torque. Once the torque occurs, high -velocity projectiles are produced causing injury or damage.

Patients with vascular aneurysm clips, implanted medical devices such as pacemakers and cochlear implants and metallic foreign bodies located in high-risk areas may impose hazard causing force and torque. Aneurysm clips may be moved by the magnet causing rupture of blood vessel and pacemaker functions are disrupted.

Aside from these, medical equipments taken inside the room such as pulse oximeter, may cause injury. Always make sure that these equipments are MR compatible and there must be care in bringing it close to the unit in its maximum operating proximity.

There is a small risk of patients receiving burns. Prior to imaging, ensure that dry flame-retardant pads are placed between cables, they are not formed into loops, and unnecessary cables are removed from the patient.

Acoustic noise may pose a particular problem to specific patient groups such as patients with psychiatric disorders, sedated patients, and neonates. The noise comes from the gradient magnetic field. The simplest and least expensive means of preventing problems associated with acoustic noise during MR procedures is to encourage the routine use of earplugs or headphones.

IN CASE OF EMERGENCY

An MR compatible crash cart should be placed near the patient, which includes medications to treat side effects and complications and all the things necessary to resuscitate patients especially during asphyxia of those who work with cryogens (liquid helium and nitrogen). Medical personnel must be around in case of emergency.

What is a Fringe Field?

Fringe field is the magnetic field that extends beyond the physical covers of the scanners. The strength and attraction of the field rapidly decreases with distance. Usually a controlled area within the vicinity of the magnet is defined to ensure safety. To guard against the harmful field, the area around the MR system must be clearly demarcated and labeled with appropriate warning signs, and monitored by trained technical staff. A person or equipment that goes near the controlled area is restricted.

SAR or Specific Absorption Rate
Usually scanners have an SAR or Specific Absorption Rate or the maximum amount exposure value. This is defined as the total power in watts (W) per kilogram of tissue. Scan parameters must be checked constantly to keep it within the permitted values. According to the International Electrotechnical Commission (IEC) 60601-2-33 is the international standard for the safety of MR equipment used for the diagnosis. The general standard on the other hand, is International Electrotechnical Commission (IEC) 60601-1. RF must be limited to a core temperature increase to 0.7°C for normal mode or 1°C for first-level controlled operations. Normal mode requires only routine monitoring of patient and first-level controlled mode requires medical supervision and a medical assessment of the risk versus benefit for the patients having the scan. Another operating mode, called the second-level controlled mode was established, which requires an approved human studies protocol to prevent unauthorized operation.

Normal operating mode has a static field exposure standard of equal or lower than 2T; first-level controlled operating modes of higher than 2T and equal to or lower than 4T; and a second-level controlled operating mode higher than 4T. Dose-effect relationship for 1.5T and 4T whole body magnets has some mild sensory effects such as vertigo, nausea and taste sensations. Others experienced headache, tinnitus, vomiting, numbness and alteration of nerve conduction.

Warning! Screen patients prior to scanning for the following:

Pregnant patients

Patients with implanted surgical clips or other ferromagnetic material

Patients with metallic implants that can cause distortion of static magnetic field that can distort the image

Patients with prosthetic heart valves

Patients whose occupation or have engaged in activities that causes accidental lodging of ferromagnetic material

Patients with tattoos, including permanent eye-liner; mostly tattoos in black or blue pigments contains iron oxide or other ferromagnetic substances are more likely to be ferromagnetic

Patient with claustrophobia or those with fear of enclosed spaces

Tips on how to minimize distress

1. Educate the patient about the MR examination.

2. Have an appropriately screened relative or friend to remain with the patient during the procedure.

3. Maintain verbal, visual, and/or physical contact with the patient during the procedure.

4. Use lights inside the MR system.

5. Use a fan inside the MR system.

6. Use special mirrors to redirect the patient's line of sight.

7. Use a video monitor for visual distraction.

8. Provide music to the patient.

9. Blindfold the patient

10. Place patient in prone position.

11. Feet-first patient entry into the magnet bore instead of Head-first.

12. Use scented vanilla oil or other aroma therapy and relaxation techniques such as controlled breathing or mental imagery.

13. Use systematic desensitization or medical hypnosis.

14. Give sedatives.

Preparing the Patient

Counseling the patient prior to imaging is very important to explain the nature of the examination. They are required to answer the questionnaire to ensure that they are a safe candidate for scanning. Ask the patient the body part to be examined, particularly confirm the laterality of the body part. Educate the patient about the aspects of the MR examination that may be challenging or difficult. Tell them about the detailed information about the procedure, level of gradient magnetic field-induced acoustic noise to expect, and the estimated time duration of the examination.

Jewelries, watches, credit cards and all metallic objects are removed before the examination. They are stored in the lockers which uses a nonmagnetic brass and plastic keys. The patients are asked to wear an MR compatible gown; because some clothing has metals on it like zippers, buttons, and underwired bras. Non-ferromagnetic MR compatible trolleys are used where non-ambulatory patients are transferred. Weight of the patient is assessed to ensure RF safety.