MR Safety
Implanted Devices
Class IV
Implanted Devices

- With Medicine grow the number of implanted devices has significantly increased in today's world.
- The large variety of implants and their sources made them a very hot topic in MRI safety.

By 2020 the number of patients with implants will have grown by 71%*

12.5 Million 2015
21.6 Million
Implants and Prosthesis

• Metallic implants present serious damaging effects, which include:
  – Torque
  – Heating
  – Artifact on the images
Screening

All individuals who may potentially enter the MR suite must be screened to guarantee their safety as well as the safety of those around them.

– Patients
– Family members / Visitors
– Ancillary staff
  • Nurses
  • Receptionists
  • Physicians
  • Environmental services staff
  • Patient support
– Emergency response
  • Security
  • Fire department

Some implants are more obvious than others.
Screening

• Who performs the screening process and how they perform it:
  – MR Level 2 personnel
  – More than once
  – Verbally and visually
  – Written
  – X-Rays
  – Ferromagnetic Detectors

• Screening form must be signed by patient or patient guardian and MR level 2 personnel.
<table>
<thead>
<tr>
<th>DO YOU HAVE ANY OF THE DEVICES LISTED BELOW</th>
<th>Yes</th>
<th>No</th>
<th>Not Sure</th>
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<tbody>
<tr>
<td>Cardiac Pacemaker</td>
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<tr>
<td>Artificial Implanted Cardiac Defibrillator (AICD)</td>
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<tr>
<td>Aneurism Clip</td>
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<tr>
<td>Cochlear (Ear) Implant</td>
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<tr>
<td>Fractured bones treated with metal roods, screws, or plates</td>
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<td>Harrington (Back) Rods</td>
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<td>Implanted Pumps</td>
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<td>Joint Replacements</td>
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<td>Magnetically Attached Dentures or Braces</td>
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<td>Neurostimulators (TENS unit)</td>
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<td>Penile Implant</td>
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<td>Programmable Shunt Catheters</td>
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<td>Prosthesis (Artificial Device)</td>
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<td>Vascular (Angioplasty) Stents</td>
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<tr>
<td>ANSWER THE FOLLOWING QUESTIONS</td>
<td>Yes</td>
<td>No</td>
<td>Not Sure</td>
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<tr>
<td>Have you had pieces of metal in your eyes from metal work, accidents or any other reason?</td>
<td>☐</td>
<td>☐</td>
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<tr>
<td>Do you have any pieces of metal in your body because of surgeries, accidents, or gunshots?</td>
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<td>Are you pregnant? ☐ Not applicable</td>
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<td>If not or unsure, list date of the last menstrual period __________</td>
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<td>Have you have surgery in the past? If yes, to what body part and when? (Please check box and enter date)</td>
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<td>☐ Head __________</td>
<td>☐ Abdomen _________</td>
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<td>☐ Neck __________</td>
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<td>☐ Spine _________</td>
<td>☐ Extremities _________</td>
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<td>☐ Chest _________</td>
<td>☐ Other _________</td>
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<tr>
<td>Have you ever been injected with IV contrast Media (Iodine or Gadolinium)?</td>
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<td>If yes, to the above question: Did you had any type of adverse allergic reaction to the IV contrast Media (Iodine or Gadolinium)?</td>
<td>☐</td>
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<td>If yes, please describe:</td>
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Additional Screening

- If no reliable patient metal exposure history can be obtained and the MR examination cannot reasonably wait:
  - A physical examination of all scars or deformities that might indicate an implant must be conducted.
  - The use of a ferro-detector either handheld or wall-mounted can help.
  - Subject the patient to plain films (X-Rays) or Computed Tomography (CT) for clearance.
Screening

• All information should be evaluated by a level 2 attending radiologist to make the final decision.
• Physician signature must be on the MRI Safety questionnaire.
• In some extreme occasions only physician signature will be required.
Before imaging a patient is very important a good screening.

In case the patient may have an implanted device, identify the device and its MR compatibility.
Implants and Prosthesis

- If the implanted device is marked as safe corroborate that is safe for the field strength that you are working with.
- There are devices safe at 1.5T but unsafe at 3T.
- All patient must bring implant specifications and must have been cleared before entering Zone IV.
Ultra-High Field

There are several safety considerations associated with field strength higher than 1.5T:

– Lack of research and testing of implants and devices
– Lack of clinical experience on humans and animals
Orthopedic Implants

- Orthopedic implants tested showed no deflection within the magnetic field.
- However, a large metallic implant such as hip prosthesis can become heated by current induce in the metal by the magnetic and radio frequency field.
- Most orthopedic implants have been image with MR without incident.
Electrically, Magnetically or Mechanically Activated Implanted Devices

- Certain devices are contraindicated or require precaution for MR imaging because they are either electrically, magnetically or mechanically activated.
- These devices include:
  - Cardiac pacemaker
  - Cochlear implants
  - Deep brain stimulator
  - Tissue expanders
  - Ocular prostheses
  - Neurostimulator
  - Bone grow stimulator
  - Implantable cardiac defibrillator
  - Implanted drug infusion pump
Electrically, Magnetically or Mechanically Activated Implanted Devices

- There are some conditions in any of these devices that must be demonstrated before scanning the patient.
  - Patient is not dependent on device to live
  - Device must be turn off
  - Patient meets clinical criteria
  - Scanner must meet device manufacturer specifications
  - Qualify staff available in case of an emergency
  - Physician available to reprogram device
Pacemaker

- Cardiac pacemakers used to be an absolute contraindication for MRI.
- Even field strengths as low as 5 G may be sufficient to cause deflection, programming changes.
- Warning signs should be posted at the 5 G line to prevent exposure of any with a pacemaker or other electronic implants.
Pacemaker

• Most pacemakers can be found on the towards the left anterior area of the thoracic cavity.

• If no history can be obtained X-Rays can help to find them.
Pacemakers

- Not always pacemakers will be found in the same body area.
Pacemaker

- Patients who have had their pacemaker removed may have pace wires left within the body.
- These could act as antenna and (by induce current) cause cardiac fibrillation.
Cardiac Pacemaker

- Modern pacemaker are being develop that are MR conditional.
- Therefore, this as any implanted device should be evaluated on case by case basis.
MR Conditional Cardiac Pacemaker

- Revo MRI Sure Scan® pacing system
- Patient Conditions:
  - Patient not dependent on pacer
  - Patient meets clinical criteria
  - The cardiologist, radiologist, company that makes pacer are present during and after the exam to reset pacer and access patient

- Equipment Conditions:
  - 1.5 T Cylindrical bore
  - Whole body SAR no more than 2 W/kg (normal mode)
  - Head SAR no more than 3.2 W/kg
  - Maximum gradient slew rate ≤ 200 T/mT/s
  - Isocenter superior to C1 or inferior to T12
Programable Shunts

- Programable shunts can be done without any restrictions.
- After examination is completed patient must go to get the neurosurgeon to reprogram the shunt.
Intracranial Vascular Clips

- Some aneurysm clips (ferromagnetic material) are an absolute contraindication in MR imaging.

- Clip motion may damage the vessel, resulting in hemorrhage, ischemia or death.
Intracranial Vascular Clips

• Titanium aneurysm clips are safe for MR but they need to be clear for the different magnetic field strengths.

• Some Titanium aneurysm clips are safe at 1.5 T and unsafe at 3T.
Intravascular Coils, Filters and Stents

- Some of these devices had been proved to be ferromagnetic, however they become imbedded (anchored) in the vessel wall by fibrous tissue (scar tissue).
- After several weeks, and unlikely to become dislodged.
Intravascular Coils, Filters and Stents

- It is recommended to delayed the exam 4-6 weeks after surgery before scanning.

- Intravascular stents, filters and coils can produce severe artifact in proportion of its size and can distort the image.
Vascular Access Ports

• Only two of 33 implanted ports tested showed measurable deflection in a magnetic field.

• This deflections are though to be insignificant.

• Therefore it is probably safe to image patients with ports.
Heart Valves

- Most patients with implanted vascular are considered to be safe for MR.
- Careful screening for valve type is advised because there are valves whose integrity could be compromised.
Dental Devices

- Some dental devices have show measurable deflection to the magnetic field. However, most are thought to be safe for MR imaging.
- Most of these devices will affect the quality of the image due to magnetic susceptibility.
- Some dental devices are magnetically activated, and therefore can pose potential risks for MR imaging.
Penile Implants

- Only one of the nine penile implants tested showed measurable deflection to magnetic field.
- It is unlikely to cause severe damage to the patient, but may become uncomfortable.
- Most of today penile implants are plastic.
Otologic Implants

- All three cochlear implants tested were attracted to the magnetic field and were magnetically or electronically activated.
- They are definitely contraindicated for MRI.
Ocular Implants

- Of the twelve ocular implants tested, two were deflected by 1.5T static magnetic field.
- It is important to identify the type of intraocular implant before to scan the patient.
External Fixators

- External Fixators should be evaluated in a case by case.
- Even if they are label as MR Safe, some of them contain ferromagnetic components (Screws or pins).
- Hand held ferro-detectors or magnets can be used for screening.
Halo

Halo vest pose several risk factors which include:

- Deflection and subsequent dislodging of the halo.
- Heating of the halo due to RF absorption.
- Electrical current induction within the halo rings.
- Electrical arcing and severe artefactual consequents.
Ferrous Foreign Bodies (Shrapnel)

- Metal in the eyes
- Metal in other body parts
- Ballistics
Intra-Ocular Ferrous Foreign Bodies

• Intra-ocular ferrous forewing bodies are a cause of major concern in MR safety.
• Patient at risk (welders, mechanics, etc) they have to be carefully screened.
Intra-Ocular Ferrous Foreign Bodies

- Methods to identify intra-ocular metal foreign bodies are:
  - Conventional Radiography
  - Computed Tomography the most accurate
Ballistics

• Although most ammunitions has proved to be non-ferrous, ammunitions made in some countries or produce illegally have shown traces of ferromagnetic alloys

• It is extremely important to identify if the patient has rest of ammunition in his body.
Ballistics

- Along with patient history and radiological images, the radiologist will make the decision.
- If the patient has bullets or fragments, it is also important to know:
  - How long ago this event took place
  - The specific location of the bullet or fragments
Decision Making

- At the end of the investigation a level 2 attending Radiologist will make the final decision if patient is to be scanned or not.
- MRI Technologist will NEVER under no circumstances make this type of medical decisions.
MRI & Pregnancy

- To date, no conclusive documentation of any deleterious effects of MRI exposure on the developing fetus.
- Pregnant patients undergoing MR exam must sign a written consent, and a radiologist or ordering physician must explain the risks versus benefits of the exam.
MRI & Pregnancy

- Pregnant patients can be accepted to undergo MRI scans at any stage of their pregnancy.
- No special consideration is recommended for the first, versus any other, trimester in pregnancy.
MRI & Pregnancy

- Pregnant health care practitioners are permitted to work in and around the MRI environment throughout all the stages of their pregnancy.
- Acceptable activities include:
  - Positioning the patient
  - Perform procedure
  - Injecting
MRI & Pregnancy

• Guidelines which exclude pregnant individuals from exposure to MRI are mainly to protect the fetus from the radio-frequency field.
Emergency Procedures

- Emergencies in MRI will be treated based on their nature:
  - Medical emergencies
  - Fire in MRI suite
  - Quench
Medical Emergencies

• As any medical facility, the MR suite should be equipped with emergency medical supplies on a crash cart.

• Ferromagnetic emergency equipment could be incredible dangerous in MR environment.

• For this reason, in any critical situation, it is recommended that the patient is rapidly removed from the magnetic field before resuscitation begins.
Fire in MR Suite

- 99% of fire inside an MR room has an electrical nature.
- The first recommendation will be shut down all electrical power source to the scanner room.
- All MR department should have MR compatible fire extinguisher with easy access to the techs and emergency service staff.
- Training to the staff of the near by fire station should be periodically done.
Quench

- Quenching is a sudden loss of absolute zero of temperature in the magnet coils, so that they cease to be superconductive and become resistive.

- This results in helium escaping from the cryogen bath extremely rapidly.
Quench

• Quenching may cause severe and irreparable damage to the superconductive coils, so a manual quench should be only performed in case of live threatening situation.
• Physician and engineer should be involved in the decision of quenching.
Quench

- The helium inside the cryogens bath is in liquid state as soon as the helium interacts with the air the helium become a gas.
- As helium vent into the room it will replace the oxygen.
- This is one of the reasons why the patient needs to be remove from the scanner room to avoid asphyxiation.
Quench

- As the helium is released, the pressure inside the MR room increases making in occasion difficulties in opening the scan room door.
- If these happens it is recommended to brake the glass between the scan room and the control room.
- MR room are design with pop-out window or an exhaust system that are designed to exhaust the helium outside the building.
Quench

• In case of a quench the number one priority is to take the patient out of the room to avoid:
  – Asphyxia (helium replace oxygen from the air)
  – Hypothermia, frostbite (helium temperature is $4^\circ K = -452^\circ F$ or $-269^\circ C$)
  – Rupture eardrums (room pressure will increase)(1 liter of liquid helium is equivalent to 760 liters of gas helium)

https://www.youtube.com/watch?v=Y9wR6k5HQfs
MRI & Pregnancy

- Although permitted to work in and around the MRI environment pregnant health care practitioners are requested:
  - Not to remain within the MR room (Zone IV) during the actual data acquisition or scanning.
Patient Management

- Patient Motion
- Claustrophobia and Anxiety
- Patient Monitoring
Claustrophobia

• The MRI scanner is an enclosed machine that may make some people feel confined, closed-in, and frightened.
• Some patients may require a sedative to remain calm and be able to lie still during the MRI study.
• Patients should be properly prepared and know what to expect.
Claustrophobia and Anxiety

- Up to 20% of patients can not complete their MR exams due to claustrophobia or anxiety.

- Therefore, it’s important to understand what can be done to minimize this problem.

- Preparing the patient with respect to specific aspects of the MR exam is the most reliable way of preventing claustrophobia and anxiety-related problems.
Claustrophobia and Anxiety

Important tips:

- Provide the patient with an educational video to watch prior to the exam.

- Patient should be given the opportunity to ask the technologist questions concerning the MR exam.

- Allow an appropriately screened relative or friend to remain with the patient during the exam.
Claustrophobia and Anxiety

Important tips:

• The technologist should maintain verbal communication with the patient via intercom system during exam.

• Play music for the patient whenever possible.

• Provide the patient with a call button in case they need any assistance.

• Make sure that the patient is positioned comfortably before starting the exam, and also positioning the patient prone or feet first will sometimes help.
Monitoring patients

- Which patients may require monitoring and support during MR procedures.
  - All patients should be monitored verbally and visually.
Monitoring patients

- Who would require additional monitoring?
  - Patients that are physically or mentally unstable.
  - Patients that have compromised physiologic functions.
  - Patients that are unable to communicate.
  - Neonatal and pediatric patients.
  - Sedated or anesthetized patients.
  - Patients undergoing MR-guided interventional procedures.
  - Patients undergoing MR procedures using experimental MR systems.
  - Patients that may have a reaction to an MRI contrast agent.
  - Critically ill or high-risk patients.
Vital Signs Monitoring

• MRI Compatible monitoring devices
  – Peripheral capillary oxygen saturation (SPO$_2$)
  – Electro cardiogram (ECG)
  – Oxygen Saturation
  – Blood Pressure
  – Temperature
MRI Safety Websites

• Implants Compatibility
  – www.mrsafety.com
  – www.magresource.com
  – www.drkanal.com
  – www.fda.com