

# Safety Issues in CMR: Commonly asked questions ?????

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## Magnetic Resonance One of the safest imaging modalities

### Advantages

- Non-invasive
- No ionizing radiation
- Repeat studies with no problem

## Is it really that safe ????

# Safety issues

Static magnetic field	<ul style="list-style-type: none"><li>- biological effects</li><li>- mechanical effects</li></ul>
Gradient Field	<ul style="list-style-type: none"><li>- currents (PNS)</li><li>- auditory damage</li></ul>
RF Field	<ul style="list-style-type: none"><li>- Burns</li></ul>
Others	<ul style="list-style-type: none"><li>- contrast agents</li><li>- critically ill patients/resuscitation</li><li>- monitoring</li><li>- quench</li><li>- claustrophobia</li></ul>

## Static magnetic field

Measured in Gauss or Tesla  
(10,000G = 1T)



1.5 T is 30,000 x the strength of earth's magnetic field

## Static Magnetic Fields

A superconducting magnet is always switched **ON** !!!!!



1. **Biological effects (potential risk)**
  - exposure to static magnetic fields of up to 4T are not harmful
  - distorted ECG (magneto-hydro-dynamic effect)
  - consider prudence with pregnancy
2. **Mechanical effects (very real risk)**
  - attractive forces on metallic objects in its field

## Static Magnetic Field Biological effects

Magneto-hydro-dynamic effect – augmented T wave



Outside field

0.5 Tesla

1.5T

## Static Magnetic Field Pregnancy

Q. I am Pregnant Can I do MRI ?

Q. I am pregnant can I work in MRI lab?

???????



???

Regular M.R.I. Is Safe During Pregnancy  
By NICHOLAS BAKALARSEPT. 20, 2016

## Static Magnetic Field Pregnancy

### Patients

- 1<sup>st</sup> trimester – prudent “advised” to avoid CMR where possible
- 2<sup>nd</sup> and 3<sup>rd</sup> trimester – decision made on a risk versus benefit determination. For example if it avoids the patient being subjected to x-rays.

### Health Care Workers

- May enter MR scanning room regardless of trimester
- Should not remain in the room when scanner is operational, avoiding exposure to gradient and radiofrequency fields

- As stated in the Policies, Guidelines, and Recommendations for MR Imaging Safety and Patient Management issued by the **Safety Committee of the Society for Magnetic Resonance Imaging in 1991**,
- “MR imaging may be used in pregnant women if other nonionizing forms of diagnostic imaging are inadequate or if the examination provides important information that would otherwise require exposure to ionizing radiation (e.g., fluoroscopy, CT, etc)

CT and MR Pregnancy Guidelines  
Guidelines for the Use of CT and MRI During Pregnancy and Lactation

## Static Magnetic Field Pregnancy

- Results of a cohort study of more than **1.4 million pregnancies** show that (MRI) in the first trimester is **SAFE**
- **BUT** gadolinium-enhance MRI at any time in pregnancy may slightly increase risk of a rare vision problem.

Published in **JAMA**, the findings are from analysis of data in a **Canadian universal health care database** and the research may be the first controlled study of first-trimester in human pregnancy.

Ray JG et al.  
JAMA. Journal of the American Medical Association  
2016;316(9):952-961

## Static Magnetic Field Mechanical effects

- **Attractive force**  
objects will be pulled out of hands, pockets. . . ., and fly into magnet which has caused injury and death.
- **Effect on ferromagnetic implants**
  - electro-mechanical eg pacemakers
  - biomedical eg valves, stents

## Potential Projectiles

- Any ferromagnetic object may be attracted to the MRI scanner and become a projectile – this is known as the **missile effect**.
- The greater the amount of ferromagnetic material, the greater the force of attraction.
- The magnetic field extends beyond the bore of the magnet in all directions (**fringe field**)

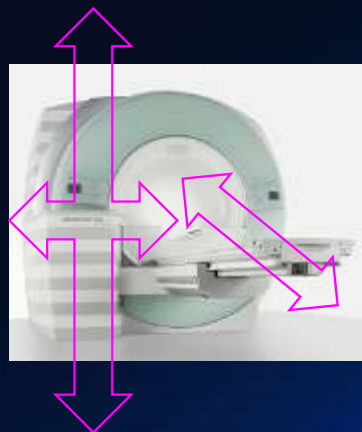


Image Courtesy of Siemens Healthcare

# MRI safety Zones

The MRI suite is divided into 4 safety zones.

**ZONE 1:** This region includes all areas that are **freely accessible to the general public**. It is typically **outside** of the MR environment itself and is the area through which patients and all personnel access the MR suite. This zone is not marked or labeled.

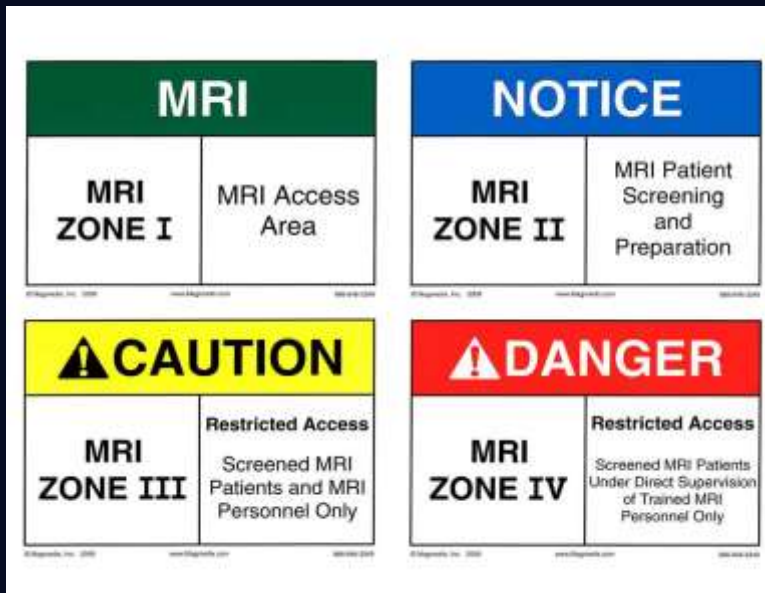
**ZONE 2:** This area is between the accessible zone 1 and the strictly controlled zones 3 and 4. Patients and other personnel are able to move throughout this area. However they must be mindful of where zone 3 begins. This area is marked with a **safety sign**.

# MRI Safety Zones

**ZONE 3:** This area is the region that **non MR safe equipment can result in serious injury or death if accidentally moved closer or into zone 4**. Personnel are not to move freely through this zone. **They must be accompanied by level 2 staff**. MR safe practice guidelines must be adhered to for the safety of the patients and other non-MR staff.

**ZONE 4 :** This zone is **the MR suite itself**. Nobody that has not been screened will enter this zone under any circumstances. If the screening process has taken place, you may enter the suite but you **MUST be accompanied by level 2 MR staff**.

# MRI Safety



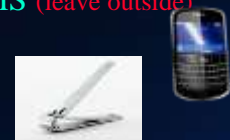
## What is typically ferromagnetic?

### EQUIPMENT

- Oxygen cylinders
- Wheelchairs
- Trolleys
- IV stands
- Monitoring equipment
- Ventilators

### PERSONAL ITEMS (leave outside)

- Keys, pens
- piercings
- Mobile phones
- Coins
- Stethoscopes
- Scissors



It is easy to forget objects, particularly when responding to an emergency!

Remember also – magnetic strips will be wiped (credit cards)



Oxygen cylinder



Floor buffer



Infusion pump



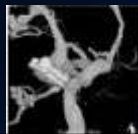
## “absolute Contraindications” to CMR

### Implants & metal

- Cerebral aneurysm clips
- Metallic foreign body in the eye
- Shrapnel, bullets (in critical area)
- Ocular implants containing metal
- Swan-Ganz
- Implanted pumps to deliver medicine
- Full mouth braces or retainers

### Electromechanical implants

- Pacemakers /ICD's
- Pacing wires
- Cochlear implants
- Neurostimulators
- Hydrocephalus shunts



# Tattoos



- Rare documented cases of
  - unusual sensation or tingling from a tattoo site
  - burns or raised skin
- Once at the center any subject with a tattoo must be informed again of the risks of tattoos in the MRI environment.
- If the subject complains of any unusual sensation during the exam → immediately stopped.
- If the area becomes red or irritated → hand cold compresses



## Implants

### Cerebral clips

- modern clips are considered safe (titanium, elgiloy)
- older clips (martensic steel is highly ferrous)
- obtain operation notes with serial number of clip
- radiologist to consent patient

### Foreign bodies

- Maybe situated near vascular or nervous tissue
- If in doubt – x-ray

## Pacemakers

- General rule has been “absolute contra-indication”
- All 3 electromagnetic fields affect pacemaker function
- *Non-pacemaker dependent patients* have been scanned *in specialist centres in exceptional cases*
- new pacemaker/lead designs may be MRI safe

\*\*2011 update: MR-conditional Medtronic pacemaker and leads now available

## Safety of Magnetic Resonance Imaging in Patients with Cardiac Devices

prospective, nonrandomized study to assess the safety of MRI at a magnetic field strength of 1.5 Tesla in 1509 patients who had

- pacemaker (58%)
- implantable cardioverter–defibrillator (42%)

that was not considered to be MRI-conditional (termed a “legacy” device).

The pacing mode was changed to asynchronous mode for pacing-dependent patients and to demand mode for other patients.

Tachyarrhythmia functions were disabled.

Outcome assessments included adverse events and changes in the variables that indicate lead and generator function and interaction with surrounding tissue (device parameters).

December 28, 2017  
N Engl J Med 2017; 377:2555-2564

# Safety of Magnetic Resonance Imaging in Patients with Cardiac Devices

In **nine** MRI examinations (0.4%; 95% confidence interval, 0.2 to 0.7), the patient's **device reset to a backup mode**.

The reset was transient in eight of the nine examinations

**change in device parameters ;**

**immediately :** decrease in P-wave amplitude (1%)

**long-term:**

decreases in P-wave amplitude (4%),

increases in atrial capture threshold (4%),

increases in RV capture threshold (4%),

increases in LV capture threshold (3%).

The observed changes in lead parameters were **not clinically significant** and **did not require device revision or reprogramming**

December 28, 2017

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2017 HRS expert consensus statement on magnetic  
resonance imaging and radiation exposure in patients with  
cardiovascular implantable electronic devices

## MRI protocols in patients with pacing devices

### Protocols typically involve;

- device interrogation and reprogramming to an asynchronous pacing mode in pacemaker dependent patients,
- inhibited modes in non-pacemaker dependent patients,
- disabling tachyarrhythmia detection and therapies in ICDs prior to the MRI study



### Medtronic's Pacemakers Now Cleared for Full Body MRI Compatibility.

Getting MRI scans while wearing an electronic cardiac implant seemed like a pipe dream only a few years ago, but lately new pacemakers and defibrillators have been developed that have conditional approvals to be used during magnetic resonance

imaging.Jan 22, 2014

## What can be safely scanned at 1.5T?

### APPROVED BIOMEDICAL IMPLANTS

#### CARDIAC

- sternal wires
- heart valves & annuloplasty rings
- coronary stents
- epicardial wires (cut short and taped)
- other vascular stents, coils and filters
- catheters (without guidewire)

#### OTHER

- orthopaedic implants
- contraceptive devices
- dental implants

Effects of implants on imaging - signal void / local distortion

## Safety Checklist – comprehensive but concise

#### Essential to know

- Cardiac pacemaker?
- Previous neurosurgery?
- Implants or metal in the body?
- Pregnant (prudent approach)?
- Drug patch with foil backing?

#### Important to know

- Previous heart surgery?
- Diabetic or epileptic?
- Asthmatic or allergies?  
(in relation to contrast)
- Tattoos or permanent eye liner (iron oxide)?

**MR Screening Form**

Patients Requiring Imaging (MRI) are screened regarding their presence with a list of items of the items below. When you are to be scanned you must be screened in order to avoid some items which could be affected by the magnetic field. Therefore, all individuals are required to fill out this form before entering the MR environment or MR (patient room). **Be advised, the MR system magnet is ALWAYS ON.**

Name: \_\_\_\_\_ Date of Birth: \_\_\_\_\_ Weight: \_\_\_\_\_

**Please indicate by checking yes or no for each of the following:**

Have you ever had a surgical procedure or insertion of any metal? If yes please list all procedures and give approximate date:	Yes	No
_____	<input type="checkbox"/>	<input type="checkbox"/>
_____	<input type="checkbox"/>	<input type="checkbox"/>
Have you ever worked as a welder, printer, writer, or heat set or had an object in the eye or on top of your head? If yes please describe:	<input type="checkbox"/>	<input type="checkbox"/>
_____	<input type="checkbox"/>	<input type="checkbox"/>
Have you ever been injured by a needle, sharp body, knife, OR sharp tool? If yes please describe:	<input type="checkbox"/>	<input type="checkbox"/>
_____	<input type="checkbox"/>	<input type="checkbox"/>

**Remove all metallic objects before entering the MR environment or MR patient room including hearing aids, magnets, all pins, all implants, hair pins, barrettes, jewelry (including body piercing, jewelry), watches, piers, piercings, metal clip, small metal, hair metal, magnetic strip cards, some some pocket tools, and clips; avoid metal tools, and tools. Lower metallic objects are especially prohibited in the MR patient room and MR environment. Please consult the MR Technologist or Radiologist if you have any questions or require MR (MRI) services the MR patient room.**

Do you have any of the following?

<input type="checkbox"/> Yes	<input type="checkbox"/> No	Cardiac pacemaker
<input type="checkbox"/> Yes	<input type="checkbox"/> No	Implant cardiac defibrillator
<input type="checkbox"/> Yes	<input type="checkbox"/> No	Artery-to-artery
<input type="checkbox"/> Yes	<input type="checkbox"/> No	Cardiac artery stent/stent clamp
<input type="checkbox"/> Yes	<input type="checkbox"/> No	Stent/stentless
<input type="checkbox"/> Yes	<input type="checkbox"/> No	Stent or stentless pump
<input type="checkbox"/> Yes	<input type="checkbox"/> No	Implanted drug infusion device
<input type="checkbox"/> Yes	<input type="checkbox"/> No	Brain prosthesis/stimulator
<input type="checkbox"/> Yes	<input type="checkbox"/> No	Cochlear, otolith, or ear implants
<input type="checkbox"/> Yes	<input type="checkbox"/> No	Any type of prosthetic eyes, joints, etc.
<input type="checkbox"/> Yes	<input type="checkbox"/> No	Artificial limbs or joints
<input type="checkbox"/> Yes	<input type="checkbox"/> No	Stimulators (on body, head, or torso)
<input type="checkbox"/> Yes	<input type="checkbox"/> No	Intracranial aneurysm, stent, or coils
<input type="checkbox"/> Yes	<input type="checkbox"/> No	Stent (spinal or intracranial)
<input type="checkbox"/> Yes	<input type="checkbox"/> No	Stent-Graft catheter
<input type="checkbox"/> Yes	<input type="checkbox"/> No	Any implant held in place by a magnet
<input type="checkbox"/> Yes	<input type="checkbox"/> No	Transcranial Doppler system (TDS)
<input type="checkbox"/> Yes	<input type="checkbox"/> No	CRP (C-reactive protein)
<input type="checkbox"/> Yes	<input type="checkbox"/> No	Tattooed shading (on face, lips, etc.)
<input type="checkbox"/> Yes	<input type="checkbox"/> No	Body piercing's (classics before MRI)
<input type="checkbox"/> Yes	<input type="checkbox"/> No	Any metal fragments
<input type="checkbox"/> Yes	<input type="checkbox"/> No	Internal pacing wires
<input type="checkbox"/> Yes	<input type="checkbox"/> No	Metal or ceramic implants
<input type="checkbox"/> Yes	<input type="checkbox"/> No	Sharing cell (classics before MRI)
<input type="checkbox"/> Yes	<input type="checkbox"/> No	Stent or Stent before MRI
<input type="checkbox"/> Yes	<input type="checkbox"/> No	Craniospinal
<input type="checkbox"/> Yes	<input type="checkbox"/> No	Pregnancy or breastfeeding
<input type="checkbox"/> Yes	<input type="checkbox"/> No	Allergic reaction to MRI contrast agent
<input type="checkbox"/> Yes	<input type="checkbox"/> No	Other allergies, etc.

Other please explain: \_\_\_\_\_

Please mark on the figure below, the location of any implant or metal inside of or on your body.



## Preparation of patient

- Remove watches / jewellery except gold wedding rings
- Remove hearing aids, false teeth, glasses, prostheses
- Remove all clothes except socks and underpants
- Screen all accompanying personnel
- Check any suspicious item with small bar magnet

# Safety issues

- |                       |   |
|-----------------------|---|
| Static magnetic field | <ul style="list-style-type: none"><li>- biological effects</li><li>- mechanical effects</li></ul> |
| Gradient Field        | <ul style="list-style-type: none"><li>- currents (PNS)</li><li>- auditory damage</li></ul>        |

## Gradient fields Induced Currents

Gradient fields induce an electric field and thus a current in the patient, potentially this can be of sufficient intensity → physiological response

- peripheral nerve stimulation (PNS)
- cardiac stimulation **XX**



## Gradient fields – Auditory damage

FDA recommended Hearing protection mandatory > 90dB

### Auditory safety

- Activation of gradient magnetic fields produces significant **vibrations** in the gradient coils → **reversible hearing impairment** and could potentially produce permanent damage.
- **Hearing protection** is recommended for all patients undergoing an MRI procedure on a high-field MRI system (1.5T and 3.0T).
- **Noise attenuating ear-plugs or head phones** are routinely used in MRI



## Safety issues

- |                       |   |
|-----------------------|---|
| Static magnetic field | <ul style="list-style-type: none"><li>- biological effects</li><li>- mechanical effects</li></ul> |
| Gradient Field        | <ul style="list-style-type: none"><li>- currents (PNS)</li><li>- auditory damage</li></ul>        |
| RF Field              | <ul style="list-style-type: none"><li>- Burns</li></ul>   |

# Radiofrequency (RF) fields

## Thermogenic effects

### Physiological tissue heating response; burn

- most of the transmitted RF power is transferred into heat within the patient's tissue
- 1°, 2°, 3° burns have occurred in the past 'e MRI As a result of excessive heat in the devices or objects
- ECG system is often the culprit
- Interventional MRI poses greater risk



## Other Issues

- Contrast agents ??
- Critically ill patients / resuscitation
- Monitoring and equipment related hazards
- Quench of superconducting magnets
- Claustrophobia ???

# What Should I do if I am going to take contrast ???



## Contrast agents

### gadolinium chelates

- overall patient tolerance high
- incidence of adverse reactions very low

### Possible reactions:-

- headache, nausea and vomiting, pain if extravasation occurs
- anaphylaxis 1:100,000

### Contraindications

- $GFR < 30 \text{ ml/min}$
- pregnancy (risk versus benefit ratio)
- breast feeding mothers
- infants  $< 2$  years

### Caution

- asthmatics, history of previous reactions

# Critically ill patients

## AICU and High Dependency Patients

- Assess patient the day before
- Lengthen and prime **IV** lines on ward
- **Replace electrodes** - carbon studs
- **Check intubation circuits for metal**
- Educate nursing staff in preparing patient

# Resuscitation

- Alert cardiac arrest team
- Call for help
- **BLS only** can be performed in scanner room
- Keep MR Compatible '**tipping trolley**' adjacent to scanner
- Patient must be moved to designated resuscitation area as quickly as possible
- Appoint non-clinical person to prevent access to scanner room
- **Practice regular 'cardiac arrest' scenarios** to identify potential problems

# Quench

Cryogenics maintain the magnetic field - helium

QUENCH = the liquid helium 'boils off' and becomes a gas

- Causes
- physical
  - human error (accidental)
  - intervention (elective)

- Effects
- ratio of gaseous to liquid helium 760:1
  - should vent to the outside, but this can fail
  - pressure build up
  - asphyxiation/frostbite



## Elective Quenching

The magnet should only be quenched in two situations:-

- If someone is trapped to the scanner by a ferromagnetic object and is injured and/or distressed (eg O<sub>2</sub> cylinder, piece of equipment)
- If there is a fire in the immediate vicinity

## Action to be taken in the event of a Quench

- Evacuate the room as quickly as possible
- Ensure the door is kept open during evacuation
- Close door after evacuation
- If trapped in room stay close to floor level
- Seek the advice of a senior physicist immediately
- Call scanner engineer

# Claustrophobia

Affects 5-10% of patients

## Causes

- restrictive dimensions of the interior of the magnet
- duration of the examination
- gradient coil induced noises
- the ambient condition within the imaging bore

## Factors to reduce anxiety

- education and explanation
- trial visit to the department
- maintaining physical and verbal contact
- presence of a relative or friend
- good communication system
- good light and ventilation
- music

## Ensuring **Safe** Practice

- Safety Checklist
- Restricted access to magnetic field area
- MR Compatible equipment ( monitors, wheelchairs, syringe pumps, stethoscopes)
- Awareness of medication common to patient area – contrast agents, stress agents
- Staff Induction
- Education and training of staff of all disciplines
- Risk Assessments
- Policies and Procedures – cardiac arrest, quench



**SAFETY FIRST**  
BE CAREFUL  
BE AWARE  
BE SAFE





*Thank You*

*Dr. Eman El Sharkawy*