



THE HARVARD CLINICAL
AND TRANSLATIONAL
SCIENCE CENTER

MRI Safety

Guidelines for safe MR practice

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<http://catalyst.harvard.edu>



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Outline

- **Introduction**
- **Safety concerns-practicing safe imaging**
- **Distress in MRI environment**
- **Patient and visitor screening**
- **Real situations**
- **References**

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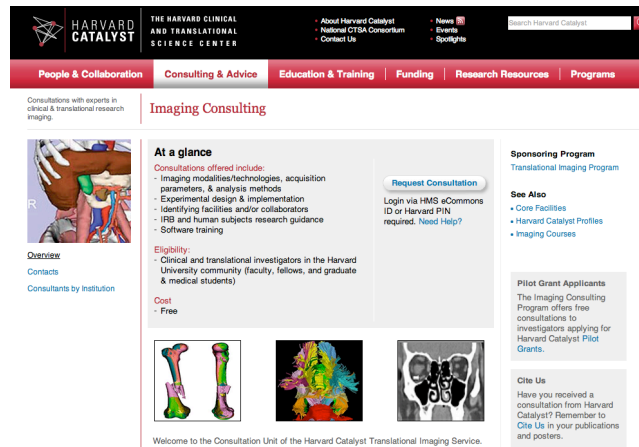
- **Provide expert consultation and guidance to the CTSC participants in the use of imaging as part of clinical translational research**
- **Educate and advise about available imaging and image processing capabilities in the Harvard environment**

Harvard Catalyst Imaging Consortium

 <p>MASSACHUSETTS GENERAL HOSPITAL</p>	<p>Bruce Rosen, Director Randy Gollub, Co-Director Gordon J. Harris, Consultant William Hanlon, Consultant</p>
 <p>Beth Israel Deaconess Medical Center</p>	<p>Robert Lenkinski, Consultant Ivan Pedrosa, Consultant</p>
 <p>BRIGHAM AND WOMEN'S HOSPITAL <small>A Teaching Affiliate of Harvard Medical School</small></p>	<p>Clare Tempany, Consultant Ron Kikinis, Consultant Charles Guttman, Consultant Todd Perlstein, Consultant Gordon Williams, PI for CTSC Translational Technologies</p>
 <p>Children's Hospital Boston <small>The Hospital for Children</small></p>	<p>Stephan Voss, Consultant Simon Warfield, Consultant</p>
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 <p>HARVARD CATALYST THE HARVARD CLINICAL AND TRANSLATIONAL SCIENCE CENTER</p>	<p>Valerie Humblet, Imaging Liaison Yong Gao, Imaging Informatics Architect</p>

Harvard Catalyst Imaging Consortium

<http://catalyst.harvard.edu/services/imagingconsult/>



The screenshot shows the Harvard Catalyst website's 'Imaging Consulting' page. At the top, there is a navigation bar with links for 'People & Collaboration', 'Consulting & Advice', 'Education & Training', 'Funding', 'Research Resources', and 'Programs'. Below this, the 'Imaging Consulting' section is highlighted. It features a 'Request Consultation' button and a 'Sponsoring Program' section for the 'Translational Imaging Program'. The 'At a glance' section lists services such as imaging modalities, experimental design, and software training. It also includes a 'Cost' section stating 'Free' and a 'Cite Us' section with a reminder to cite the service in publications and posters. The page is decorated with several anatomical and medical images, including a hand, a leg, and a brain scan.

Objectives

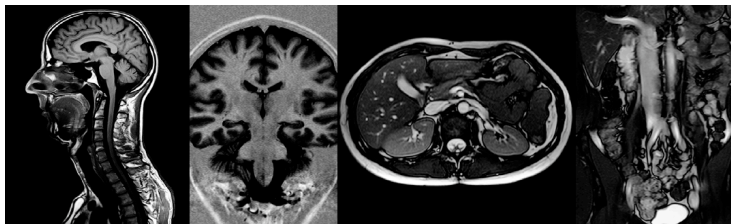
- **Learn potentials risks in MRI environment**
- **Learn guidelines to safe MRI practice**
- **Tools to answer patient/subjects about MRI procedures**

Introduction

- **Magnetic Resonance Imaging (MRI) has been in use for over two decades and is viewed as a medical procedure associated with acceptable and well controlled risks.**
 - However, there are potential risks in the MRI environment.
 - This document is a compilation of the MR safe practice guidelines from the following institutions:
 - BIDMC, BWH, CHB, DFCI, MIT and MGH

What is MRI?

- **MRI is a noninvasive, high resolution 3D imaging modality that produces good contrast between the different soft tissues of the body, which makes it especially useful in imaging the brain, the muscles, the heart and cancers.**



1st thoughts of MRI

- **Powerful super conducting magnets, field strength,**
 - 1.5T, 3.0T, 4.0T, 7.0T..., etc.
- **Claustrophobia – “coffin like tunnel/tube”**
- **Long scan times, minutes to hours**
- **Loud banging/clanking noises**
- **Gadolinium contrast - NSF**
- **Expensive**
- **Pretty pictures**
- **Isolated environment**

The MRI system



The MRI system

- **3 types of magnetic field:**
 - **Large superconducting magnet producing main magnetic field.**
 - High field magnets are 1.5T or 3T
 - For comparison, 1.5T = 25,000 times the magnetic field of the earth
 - **Radio Frequency field (RF)**
 - RF transmission can affect electronic devices
 - **Magnetic field gradient**
 - They are turned on/off very quickly during scanning, causing the knocking noise associated with MRI

Reported MRI Accident

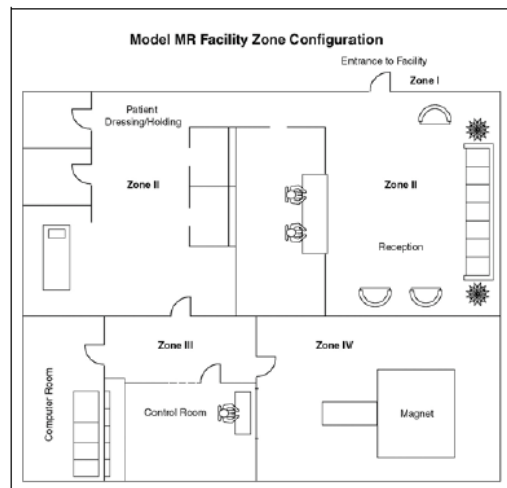
- **A patient with an implanted intracranial aneurysm clip died as a result of an attempt to scan her. The clip reportedly shifted when exposed to the magnetic field. The staff apparently had obtained information indicating that the material in this clip could be scanned safely. (11/11/92)**

Reported MRI Accident

- On July 1, 2001 a 6 year old sedated patient was killed when a O2 tank was “Introduced into the exam room”. This magnetized object was drawn to the center of the room, striking the boy.

Cohen et al, (2004)MRI Safety: a Primer. Retrieved on 12/01/04
<http://airto.loni.ucla.edu/BMCweb/Safety/SafetyTutorial/index.html>

MRI site access restriction



**The MR site is
conceptually
divided into four
zones**

Zone 1



- **Patient waiting area, easily accessible, no restrictions. No safety screening questionnaire needed.**
- **Safe for Code team response.**

Zone 2



- **Area of initial contact. Semi restricted. Patient screening can be accomplished in this zone. Area where medical emergencies are handled.**

Zone 3



- **Control Room: physical restriction for non MRI personnel. Pacemakers can be affected in this area as a result, free access might result in serious injury or death.**
- **Screening form must be completed to enter this area**

Zone 4



- **Magnet Room: physical restriction for unaccompanied non MRI personnel. Free access might result in serious injury or death.**
- **Screening form must be completed to enter this area.**

Safety concerns

- **Projectile/missile effects**
- **Implanted devices (pacemakers, ICDs)**
- **Nerve stimulation**
- **Auditory issues**
- **Thermal heating**
- **Cryogenic liquids/quench**
- **Contrast agents**
- **Pregnancy**
- **Pediatric**

Projectile/Missile Effects

- **Most immediate danger: attraction between the magnet and ferromagnetic metal objects**
 - **Those objects can become airborne projectiles**
 - **Even hand-held objects can be jerked free very suddenly as the holder moves closer to the magnet**
- **Remember, even when you are not scanning, the magnet is not "off". NEVER bring any metal objects into the scanner rooms.**

Projectile / Missile Effects

- **Oxygen tanks must be MRI safe**
- **Be cautious if a patient/subject is brought in with an oxygen bottle**



Oxygen tank

- <http://www.youtube.com/watch?v=7g5UVrOt2CI>

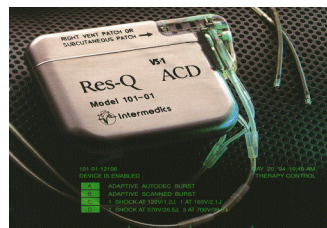
What Can Happen?



www.SimplyPhysics.com

Implanted Devices

- **Pacemakers, cardiac defibrillators, medication pumps, nerve stimulator devices and other devices can be affected by the magnetic field.**
 - **Cardiac pacemakers: magnets may induce arrhythmia, bradycardia, tachycardia**



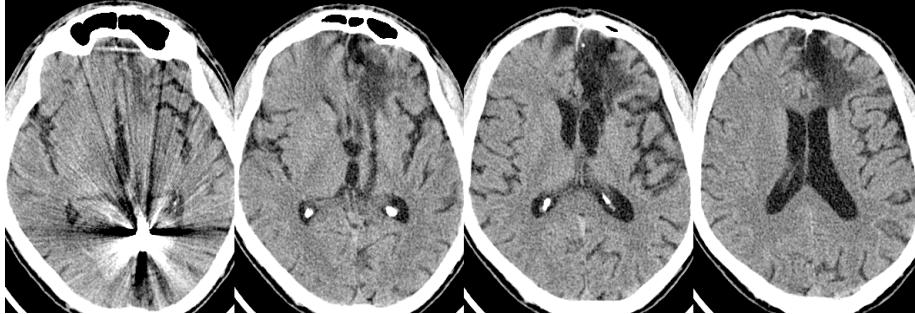
Implanted Devices

- **Aneurysm clips:**
 - Need document proving they are MR safe
 - Artifacts, even with safe clips
- **Heart Valve:**
 - Most are safe but positive documentation must be obtained
 - Many have been evaluated and showed mild rotation torque on the system. But, these forces are minimal compared to the force exerted by the beating heart

Metal in the body

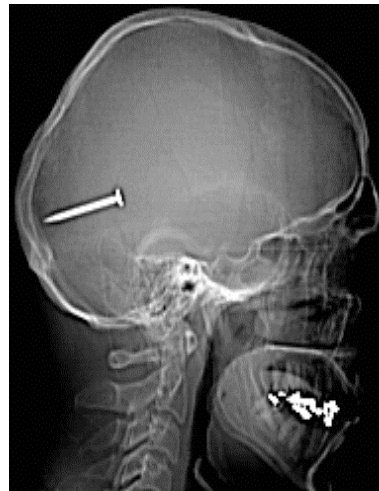
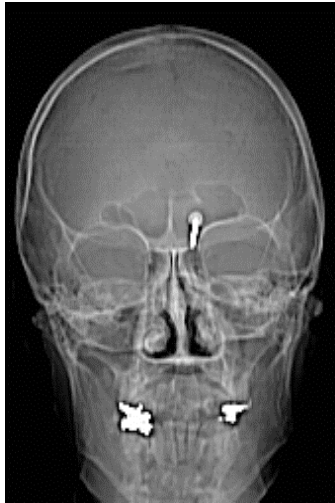
- **Torque and Heating:**
 - metallic implants can show considerable torque.
 - Non-ferrous metallic objects may show little or no deflection, but could still heat.
- **In addition, metal in or near the body (such as dental implants) can produce artifacts, which adversely effect image quality.**

45 y.o. male 2+ years after altercation



Thanks to A. Greg Sorensen / MGH

45 y.o. male 2+ years after altercation



Thanks to A. Greg Sorensen / MGH

Nerve stimulation

- **Exposure of conductive tissue to time-varying magnetic fields will induce an electric field.**
 - **Nerve stimulation: mild skin sensations and involuntary muscle contractions**
 - **Patients should not have their hands clasped, hands should be positioned by their side. Ankles should not be crossed either**
 - **Magnetophosphenes: visual sensation of flashes of light due to retina stimulation**

Auditory issues

- **Strong, static magnetic field in conjunction with gradient magnetic fields produce mechanical forces and motion. The result is acoustic noise.**
 - **Study showed temporary hearing loss in 43% of subjects** (Brummett et al, Radiology 1988)
 - **Patients should always be given noise reducing protection , in the form of earplugs or headphones during scanning**

Thermal Heating

- **Radio-frequency fields cause energy dissipation in the form of heat into body tissues**
- **The safety standards are designed to ensure that no tissue is subjected to a temperature increase of over 1°C**
 - **Guidelines for industry and FDA staff:**
<http://www.fda.gov/cdrh/ode/guidance/793.pdf>

Electrical burns

- **RF fields can cause burns by producing electrical currents in conductive loops.**
 - **Only minor temperature changes reported in implanted devices**
 - **Transdermal patches with metallic backing must be removed (FDA warning 03/09)**
 - **“Red Dot” ECG leads must be removed**
 - **Looped ECG leads, pulse oximeter cables, etc. can cause burns**
 - **Dark tattoos may cause heating**

What is a quench?

- **Rapid loss of magnetic field, 20-30 seconds.**
 - liquid cryogenes boil off rapidly



Ref: www.americanmagnetics.com/tutorial/quench.jpg

Cited from, Stephen J. Powers BSRT,R,CT,MR

The quench

- **A quench:**
 - should **ONLY** be performed by authorized personnel with proper training
 - in dire emergency that involves a serious personal injury.
- **A quench could damage the magnet or components of the system. There is a considerable cost related to quenching the magnet and re-implementing the magnetic field.**

Ref: www.americanmagnetics.com/tutorial/quench.jpg

Quench

- **In the event of a quench**
 - **Evacuate all persons**
- **In the process of a quench**
 - **If venting system fails, cryogenics will fill scanner room ↑ pressure potential ear drum rupture**
 - **Asphyxiation can occur from breathing helium. Oxygen is displaced**
 - **Hypothermia & frostbite, the temperature of liquid helium is approximately -269 degrees C or 4.17 degrees K.**

Reaction to contrast agent

- **Anaphylactic reactions are rare but do occur.**
 - **In case of severe reaction, administration of epinephrine with auto injector device (0.5 mg of 1:1000 concentrated epinephrine to be given intramuscularly in the lateral thigh, lower dose for people under 50 kg)**
 - **The auto injector should be within easy reach, for example in an emergency tackle box**

Nephrogenic systemic fibrosis (NSF) & Gadolinium

- **Nephrogenic systemic fibrosis (NSF):**
 - **Newly discovered disease (1997) associated with the use of Gd-based MRI contrast agents in patients with severe renal disease disorder**
 - **Characterized by thickening and hardening of the skin and immobility or tightening of the joints**
 - **Screening for risk factors for kidney disease (> 60 years, diabetes, systemic lupus erythematosus, history of renal disease, multiple myeloma) is crucial**

Nephrogenic systemic fibrosis (NSF) & Gadolinium

- **It is advisable that no patient with an eGFR of <30 ml/min/m² (Stage 4 or 5 kidney disease) should receive Gd contrast agents unless the benefits are deemed to outweigh the risks. No injection for research.**
- **Consultation with a radiologist is suggested before administering Gd contrast agents to a pediatric patient or a patient with a eGFR of <60 ml/min/m²**
- **No radiologist consent needed eGFR >60**

- **No known adverse effects on fetuses**
- **Research:**
 - **Given the scarcity of data it is not worth the risk for pregnant women to participate as subjects in MR research studies**
- **MRI technologists:**
 - **Most clinical units allow pregnant employees to enter the scan room, but not to remain in the room while the RF and gradient fields are applied during image acquisition.**

- **Clinical:**
 - **MRI used to evaluate obstetrical, placental, and fetal abnormalities in pregnant patients for more than 20 years.**
 - **Before an MRI procedure:**
 - **Is sonography satisfactory for diagnosis?**
 - **Is the MR procedure appropriate to address the clinical question?**
 - **Is obstetrical intervention prior to the MR procedure a possibility? That is, is termination of pregnancy a consideration? Is early delivery a consideration**

- **Contrast agents and pregnancy**
 - **Studies of gadolinium-based MRI contrast agents in pregnancy have been limited, and effects on the embryo or fetus are unknown.**
 - **Gadolinium-based MR contrast media cross the human placenta and are found into the fetus when given in clinical dose ranges**
 - **MR contrast agents should not be routinely provided to pregnant patients.**

- **Sedation and monitoring**
 - **Largest group requiring sedation because of inability to remain motionless**
 - **Sedation protocol subject to institution review**
 - **Neonatal and young pediatric population, special attention needed in monitoring body temperature**
 - **MR compatible equipment commercially available (warming devices, monitoring, incubator)**

Pediatric MRI

- **Screening issues**
 - **Children may not be reliable, should be questioned both in presence of parents/guardians and separately**
 - **Stuffed animals and other comfort items represent real risk. Some facilities have a choice of safe toys for kid to choose during scanning time**

Distress in the MRI environment

- **Incidence of distress among MRI is high**
- **Distress can be caused by many factors including: confined space, noise, restriction of movement**
- **Distress can range from mild anxiety to full blown panic attack**
- **Distress can result in subject motion and disrupt image quality**

Distress in the MRI environment

- **Minimizing subjective distress**
 - Careful screening
 - Complete explanations on the aspect of the MR examination
 - Make them comfortable in the scanner
 - Maintain verbal contact
 - Use mock scanner if available
 - Give them the panic button

Patient and visitor screening

- **All persons undergoing an MRI examination, regardless of their medical conditions, must either complete the screening form or have one completed by a relative/healthcare proxy.**
- **Screening forms available for each institution**

Patient and visitor screening

- **Conditions that rule out a patient/subject**
 - **Cardiac pacemaker**
 - **Surgical aneurysm clips**
 - **Neurostimulator**
 - **Implanted pumps**
 - **Metal in body/eyes. Patient must be cleared by a radiologist (usually via routine Xray)**
 - **Pregnancy (for research)**

Patient and visitor screening

- **Conditions that might rule out a patient/subject:**
 - **Ear implants (certain cochlear implants are not OK)**
 - **Metal rods, plates or screws in body or mouth**
 - **Previous surgery (if metal left in body)**
 - **IUD (most are OK except Copper-7)**
 - **Hearing aid (should be removed)**
 - **Dentures (should be removed)**
 - **Prosthetic heart valve (most are plastic now)**
 - **Braces (causes severe frontal artifact)**
 - **Hair extensions**
 - **Tattoos or permanent eyeliner (if ink contains metallic specks)**

Patient/subject preparation

- **Individuals must remove the following:**
 - **Jewelry, even if pure gold. Exception wedding bands which cannot be removed.**
 - **Hearing aids**
 - **Body piercing**
 - **Watches**
 - **Hair holder**
 - **Metal on clothing (belt, metal buttons, underwire bra)**
 - **Any magnetic media (credit card), electronic devices (cell phones, beepers,...) will be damaged**
- **Most hospitals required patient/subject to change into a hospital gowns**

Prior MRI scans

- **Do not consider the individual's history with prior scans as a reason to bypass screening. Exception: patient was scanned within 24 hours (or within the same day), and screening form is accessible.**

Real situations

- **You suddenly discover the patient has a ferrous magnet clip and the patient is already in the scanner:**
 - **Remove the patient slowly from the system**
- **A metal worker has had several MRI's from outside institutions:**
 - **You still need documentation that there is no metal presence in the eyes. Must obtain orbits prior to imaging.**
- **An IV pole is inside the bore, but no one is hurt:**
 - **You should immediately call service. In trying to remove the object you can cause harm to yourself and/or another individual**

Real situations

- **Medical emergency:**
 - **No resuscitation equipment in the magnet room**
 - **Initiate basic life support or CPR as required by the situation while the patient is removed from Zone IV**
 - **To move the patient from magnet room to holding area, undock the table (if possible) or use a MRI compatible stretcher to move the patient**
 - **Call emergency personnel**

Current FDA Criteria for non-significant risks

- **Field strength < 8T for anyone aged one month and older**
- **SAR < 3 W/kg averaged over 10 minutes in head**
- **SAR < 8 W/Kg in any 1 cc of tissue in head averaged over 5 minutes**
- **Acoustic Noise <140 dB peak and 99 dB average with ear protection**
- **No painful or severe peripheral nerve stimulation**

References

- www.mrisafety.com
 - List with information for over 1,200 implants, devices, materials and products (over 200 tested at 3T)
- http://www.acr.org/SecondaryMainMenuCategories/quality_safety/MRSafety/safe_mr07.aspx
- <http://www.imrser.org/Default.asp>

References

- **Description of procedures, how to prepare for it:**
 - <http://www.radiologyinfo.org/>
 - <http://www.medicalimaging.org/>

Acknowledgments

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