



**Center for Advanced Brain Imaging
Georgia State University and Georgia Institute of Technology**



Magnetic Resonance Imaging (MRI)

Safety and Operations Manual

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1 MRI Safety Policies and Procedure Overview

1.1 Introduction

Georgia State University and Georgia Institute of Technology Center of Advanced Brain Imaging is committed to provide a safe and healthy research environment. The center includes a Magnetic Resonance Imaging (MRI) suite that can acquire images of the human body. Used properly, MRI is extremely safe. However, in order to be used safely, users need to be familiar with the potential hazards involved with MRI. This manual describes these hazards and outlines the safety hazards, and supplements the center's MRI safety training.

1.2 Facility

The Center of Advanced Brain Imaging is dedicated solely for research. The center houses a Siemens 3Telsa Magnetom Trio (B15 Software), which has the state-of-the art two-dimensional {2D} and three-dimensional {3D} functional, structural and dynamic imaging.

1.3 Staff Contact Information

The staff of the center is responsible for the safe operation of the MRI scanner, and to help researchers ensure that their work is in compliance with the Institutional Review Board. However, if you have any questions or concerns please do not hesitate to call a member of the staff for assistance.

Name	Phone Number	Alternate Number	Email
Dr. Christopher Rorden, Director	(404)385-8621	(803)873-3255	rorden@gatech.edu
Lei Zhou Physicist	(404) 712-2710 or (404) 385-8624	(404) 326-1678	lzhou5@emory.edu
Jaemin Shin Research Assistant	(404) 385-8624	(734) 709-4991	jaemins@gatech.edu
Nytavia Wallace Research Technologist	(404)385-8629 Or (404)385-8631 (MRI control room)	(770) 842-3302	nwallace3@mail.gatech.edu

1.4 Tours and Visitors

The center's primary mission is research, and participant privacy and our other duties limit the staff's ability to provide open access to visitors. If you are interested in scheduling a guided tour for a visitor, please contact the Director to organize a visit. If researchers are permitting visitors into the center, it is their responsibility to make sure that all individuals are pre-screened and that the participant's privacy is not being compromised. Potential researchers should contact the staff to schedule a safety tour, which is part of our training procedures. (see Section 2)

2 MR Safety Training Procedures

Safety Training is required for all researchers and staff, who will be utilizing the MRI system. The training will consist: of an organized tour that will introduce the MRI control area, scanner, and equipment room. Users of the MR system will also:

- Watch a 23- minute safety video
- Complete a current MR screening form for yourself, and it is your responsibility to update the Research Technologist if you every have any concerns about metal items in your possession or within your body.
- Attending a 90-minute MRI Safety Training Course
- The researcher(s) are responsible for obtaining approval for their research and the use of the MR scanner. This includes:
 - Obtaining the proper IRB (Institutional Review Board) approval.
 - Getting the protocol reviewed and approved.

If you would like to arrange a safety training contact:

Nytavia Wallace RT(R) MRI
404)385-8629 or 770)842-3302
nwallace3@mail.gatech.edu

2.1 Additional MRI Safety Resources

The international recognized internet web-sites contain some extensive MRI safety information. Frank Shellock, Ph.D. is the world renowned MR safety expert and his website is <http://www.mrisafety.com>. Another good valuable resource is the International Society of Magnetic Resonance in Medicine (ISMRM) and this website is <http://www.ismrm.org>.

3 Principles of MR Imaging

THE SCANNER IS ALWAYS ON. A serious hazard for MRI safety is allowing object to become attracted to the static magnetic field. This can result in an individual being struck, injured or trapped against the magnet by the object. Equipment can also become damaged by slamming into the magnet or being struck by another object that is accelerating rapidly due to the strong attraction of the magnetic field. There are three main component of the MRI scanner: the static magnetic field, the radiofrequency field, and the gradient or time varying magnetic field.

3.1 Static Magnetic Field

The static magnetic field is the main magnetic field that is always present once the scanner is ramped up to the designated field strength. This field is described in units of Tesla (T) or Gauss (1T = 10,000 gauss). Our system uses a 3T static magnetic field, approximately 60,000 times stronger than the earth's magnetic field that induces a compass to point North. The distance for the magnet that is safe for the general public and to use all objects and devices is denoted as the 5 gauss line. The researcher(s) must be aware of the fringe field, before deciding to take objects into the scanner room.

3.2 Radiofrequency Field

The radiofrequency (RF) coil is the heating source within the scanner. This system uses coils as transmitters to excite the MRI signal and as a receiver to detect the MRI signal. It is important to properly use the equipment and accessories of the MRI scanner.

3.3 Gradient/Time varying Magnetic Field

The gradient or time varying magnetic field selects the slices and imaging planes. This particular field is superimposed over the static magnetic field, and is the sources of all the acoustic noise. The coils within this system are pulsed on and off to produce linear gradients of the magnetic field for imaging. This allows producing an array of images with different spatial and temporal resolutions, and with different contrast between tissues in the image.

4 Risks of MRI

The major risks that are associated with careless use of the MRI scanner are:

4.1 Projectiles

Items that are ferromagnetic have the potential of becoming projectiles when introduced to the magnetic field. Objects with ferrous properties can rapidly accelerate when captured by the magnetic field. Projectiles have the potential to cause serious injury or even death, to anyone who may be in the path of the acceleration. In addition, the equipment may be irreparably damaged. One way to prevent this from happening is to always remove all metallic objects and being cognizance of the ferrous metallic detector when entering the MR scanner room. If it alarms when you or an individual have entered the room; then there is some metal present. **(Incidents involving projectiles are to be reported to the Research Technologist.)**

4.2 Torsion and Translation Forces

Ferromagnetic objects or devices will be attracted to the magnetic field. Those ferrous objects such as brain aneurysm clips, metal fragments in the eyes, and/or implanted medical device within the body, will attempt to align themselves with the static magnetic field. This can be avoided by properly pre-screening all individuals that will enter the MRI suite.

4.3 Magnetohydrodynamic Effect

Due to the field strength of the MRI scanner it is possible to undergo the effects of vertigo and nausea. These are all effects associated with the magnetohydrodynamic phenomena. This most often occurs when research participants make quick head movements while in the scanner. This is also a possible occurrence when research participants are moved from the magnetic field. One way to prevent this from occurring is to instruct the research participants to arise from the supine position slowly.

4.4 Voltage and Electrical

Due to the conductivity of the MRI scanner, objects that have the ability to produce voltage shall **NOT** be taken into the scanner. (No objects with loose wire or circuitry) This also applies to electrical devices. {i.e. Implanted Pacemaker, Aneurysm Clip, Implanted CardioDefibrillators, Cochlear, Brain Stimulators, etc}The electrical devices could malfunction, when subjected to the magnetic field.

4.5 Radiofrequency Heating and Inducing Electrical Current

The RF pulse can cause an object to warm up. This is somewhat analogous to a microwave oven. In typical usage, these warming effects are very minimal. The FDA sets clear guidelines for the amount of warming allowed (measuring the Specific Absorption Rate or SAR), and the scanner will not allow you to exceed these limits. The common sequences used in our center tend to be well within these limits. However, if you are planning to scan small participants such as children, you may want to work with the center staff to ensure that the sequences are suitable for your intended population. When registering a subject into the scanner for imaging purposes, it is important to input near to exact weight, to ensure the SAR is calculated correctly. It is also imperative to make sure the research participants do not interlock any of their body parts this is an easy way for the subject to receive nerve or burning sensations.

4.6 Suffocation

In rare situations (such as quench, see below) the scanner might release a large amount of helium gas that will rapidly force all of the oxygenated air out of the room. Under normal circumstance, this helium gas is vented through the roof of the facility; however this is possible if the ventilation system fails. The scanner hall at our center is equipped with an oxygen sensor, which will sound an alarm if there is less than 19.5 % oxygen in the air. If this alarm sounds, you should evacuate the building until told to reenter by the staff.

4.6 Acoustic Noise

The acoustic noise associated with MR imaging is related to the mechanical movement of the gradient coils during the scanning process. Though the noise is perceived to be of non-significant risk while lying in at 3T scanner, FDA recommends the use of earplugs or headphones.

5 Contra-indicators of MR

There are equipment, devices, medical implants, etc that are at risk to injury and/or damage if they are entered into the scanner room. This pertains to be within the body or in personal possession. The items that are listed are considered to be potential risk to an individual's safety. Some items on the list are conditional (*), and further information can be founded at www.mrisafety.com.

5.1 The List of Unsafe Devices

Aneurysm Clips	Shunt
Cardiac Pacemaker	Vascular access port and/or catheter*
Implanted cardioverter defibrillator (ICD)	Radiation seeds/implants
Electronic Implant or Device	Swan-Ganz (thermodilution catheter)
Magnetically-activated implant/device	Mediation patch (Niction, Nitroglycerin)
Neurostimulation system (Deep Brain)	Any metallic fragment/foreign body
Neurostimulation system (Urinary Control)	Wire mesh implant
Spinal cord stimulator	Tissue expander (e.g. breast)
Internal electrodes/wire	Surgical staples, clips, or metallic sutures*
Bone growth	Joint replacement (hip, knee, etc.)*
Cochlear, otologic, or ear implant	IUD, diaphragm, or pessary
Insulin or infusion Pump	Dentures or partial plates*
Implanted drug infusion pump	Tattoo or permanent makeup
Prosthesis (eye and/or penile)	Body piercing jewelry
Heart valve prosthesis	Hearing aid*
Eyelid spring/wire	Other implant
Artificial or prosthetic limb	Breathing problems or motion disorder
Metallic stent, filter, coil*	Claustrophobia

6 Safety Pre-Screening

The pre-screening is necessary for researchers, research participants, and individuals entering into the MRI control room. Each individual must be screened for safety **PRIOR** to entering into the MRI control room. Research participants must fill out the screening from each time they enter the MR scanner. A standardized form will be used to evaluate individual safety for entrance into the MRI scanner.

It is mandatory to pre-screen all individuals and the screening form needs to be completely filled out and signed. In addition to the screening form, the individuals that are entering into the MRI scanner must either walk through a functioning ferromagnetic detector or be waned with the handheld metal detector. **This policy will be strictly enforced.**



Figure 1: The ferromagnetic detector lines the door into the scanner room.



Figure2: The handheld metal detector should be used if the ferromagnetic detector is not functioning.

Other items of concern are orthodontic braces, permanent makeup/eyeliner, and tattoos. Orthodontic braces generally do not constitute any risk, though they make obscure your image. Meanwhile, research participants with permanent makeup/eyeliner and tattoos could possibly experience some irritation and redness from the site. If there is every any doubt about the safety of a subject do not hesitate to consult with one of the safety officers.

Some implanted devices are completely safe for 3T MRI, but our policy is to err on the side of extreme caution. The Researcher is responsible for finding out if presented medical devices are MRI safe, and make sure that the findings are discussed with the Research Technologist. All belts and jewelry with the exception of wedding bands should be removed and securely locked in provided lockers for subjects. In addition, prior to entering the magnet hall everyone should remove metal and electronic objects including mobile phones, watches, and hair bands. In addition, be aware that many shoes include steel shanks. Please ensure that participants either remove their shoes outside the scanner or are keep their shoes on securely while in the scanner.

7 Other Precautions

7.1 Ear Plugs and Headphones

Any individual in the MR scanner room during the operation of the scanner must protect their ears. This includes the person lying in the scanner as well as any observer who want to stay in the scanner room during imaging (e.g. an adult who wants to reassure a child). Both earplugs and headphones are provided to avoid possible hearing injury and/or discomfort.

7.2 Laser Light Localization

A laser light is used to “land mark” research participants in the scanner. Before the research and/or operator activate the laser light, make sure that the participant has closed their eyes. This will eliminate possible eye injury. If the laser light does not appear as a crosshair, it should be immediately reported to Center of Advanced Brain Imaging Staff.

7.3 Phantom Leaks

The term “phantom” refers to the bottles used to test the quality of the MR images. These bottles come in many shapes and are filled with different liquids that are specific to scan protocols. The liquid sealed inside a phantom may be toxic (e.g. copper sulfate is often found in fiducial markers and ingested can induce vomiting and other symptoms). If a phantom appears to have leaked, please contact the staff. This leaking object should only be moved by someone wearing protective clothing, (gloves, lab coat, goggles, and face mask), and then dispose of the hazardous material. {This material should **NOT** be poured down the drain.}

7.4 Pregnancy

There is currently no established regulatory guideline for exposure of pregnant women to the MRI system. Evidence, however, within the clinical setting FDA recommends delaying the study until after the pregnancy if possible. Furthermore, pregnancy is associated with an increased risk of vomiting, which can cause problems in the confined spaces of a scanner. For this reason, the center does not scan pregnant women, and we encourage them to return after their pregnancy.

7.5 Obese Research Participants

Due to the Siemens Trio scanner design, we must exclude research participants weighing more than 400 pounds from being scanned. The Siemens Trio scanner bed is designed to support weights up to 440 pounds, however due to the diameter of the bore, anyone over 400 will not be comfortable. In addition, staff needs to be able to help a participant evacuate the scanner in the event of an emergency, and this is more challenging with heavy individuals.

7.6 Children

Children are allowed to enter the MRI scanner room as research participants in an IRB (Institutional Review Board) approved research study. Only children who are participating in a study are allowed to enter into the scan room, and only are allowed into the MRI control room if accompanied by an adult. The MRI equipment room is completely off limits to the children.

The same safety precautions apply to adults who will accompany their child/children while participating in research. This will assist any minimizing risk within the Center of Advanced Brain Imaging.

8 Emergency Safety Procedures

In the event of an emergency it is important to ensure the safety of individuals, researchers, and research participants. It is essential that each research participants have constant communication, with the researcher and scanner operator, while in the MRI scanner. Each research participate should be given the signal squeeze ball that can be used to alert the scanner operator, if a problem should arise.

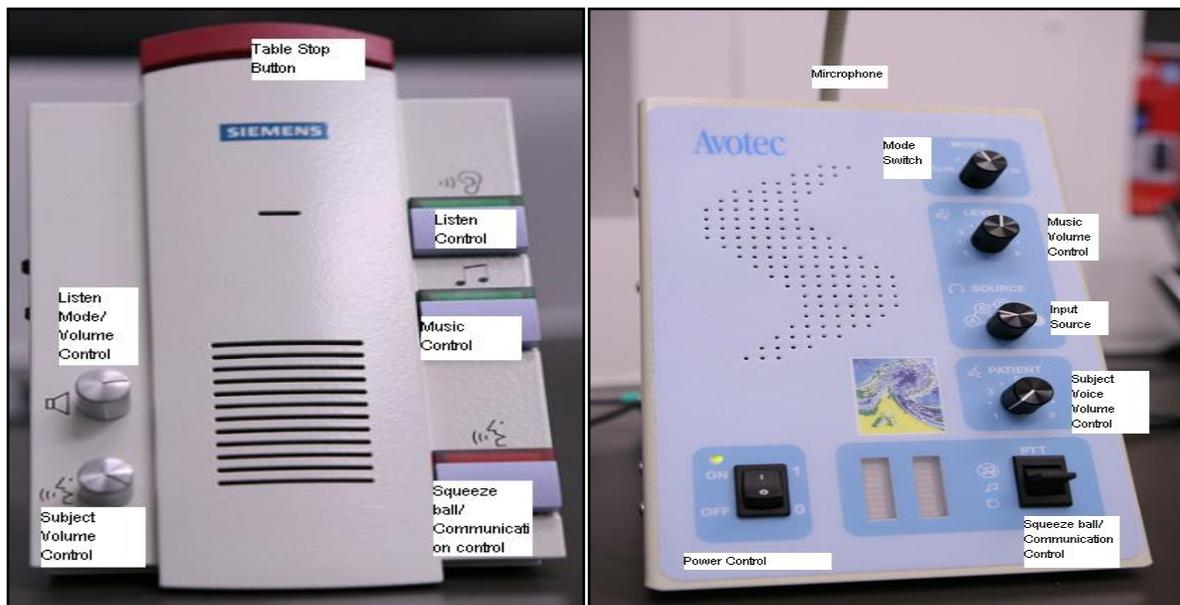


Figure 3: Either one of the systems show can be used to communicate with the research participant

8.1 Medical Emergency

In case a research participant or other individual becomes ill or is injured the individual should be assisted out of the MRI scanner room and into a secure place at least out of the gauss range; then a call for assistance. **{There is a MRI compatible wheelchair available; it will be located in the MRI scanner. This is the only piece of equipment that is allowed in the room}**. This type of event also needs to be reported to a Staff Member.



Figure4: This label on this side near the rear tire is the indicator for the MRI compatible wheelchair.

8.2Emergency Stop

If there appears to be smoke coming from the MRI scanner, equipment room or console, it is necessary to activate the emergency stop. The emergency stop will immediately shutdown electricity to the scanner. This is also necessary if you witness water in the MRI equipment room. There are two emergency stop buttons: one located in the MRI control room and one located in the MRI scanner room and they both look identical.



Figures: The emergency electrical shutdown button does not shutdown the magnet field.

Emergency Electrical Shutdown Procedure

1. Remove the research participant from the scanner room. If the participant is in the bore of the scanner and the table will not move, there is an emergency lever on the left side of the table, labeled {Emergency Release}. Pull the lever, and then pull the table to release the participant from the scanner.

2. Locate one of the two electrical shutdown buttons (control room/scanner room). It is only necessary to press one of the large red electrical buttons. **Make sure that this is the electrical shutdown button, not the quench button.**
3. The electrical shutdown will immediately stop all power to the scanner, scanner equipment, and computer console.
4. If there is a fire or medical emergency, call 911.
5. Notify GSU/GT Center of Advanced Brain Imaging staff that you have performed an Emergency Electrical shutdown.

8.2 Magnet Emergency

If an individual or research participant is restrained or pinned by a ferrous object to the magnet: Assess if the situation is life threatening, if **YES** an emergency quench can be performed by an authorized staff member. If the situation is **NOT** life threatening, call for assistance to determine the optimal way of releasing the individual or research participant.

8.3 Emergency Quench

A quench is a rapid release of cryogenics (liquid helium) and results in a loss of the magnetic field. A quench should **ONLY** be performed by authorized personnel in a dire emergency that involves a serious personal injury or life threatening situation. Sudden loss of the magnet field can result gases entering the MRI suite. There is also a considerable cost related to quenching the magnet.

Before activating the quench button make sure everyone (i.e. research participant, researcher, scanner operator, etc) is out of the scanner room. This will avoid possible helium asphyxiation.

The quench button is located in the MRI control room to the right of the scanner console, and is covered with Plexiglas. The actual button has “**STOP**” printed within the perimeter.



Figure6: The magnet quench will result in complete shutdown of the magnet and all associated software and hardware.

Emergency Quench Procedure

1. Remove the research participant from the scanner room. If the participant is in the bore of the scanner and the table will not move, there is an emergency lever on the left side of the table, labeled {Emergency Release}. Pull the lever, and then pull the table to release the participant from the scanner.
2. Make sure that the MRI scanner room is wide open.
3. Locate and press the Quench Button in the control room of the scanner. Left the Plexiglas to gain access to the button.
4. The magnetic field will become unsafe in a matter of 20 seconds; therefore remove everyone from the MRI suite.
5. Notify GSU/GT Center of Advanced Brain Imaging staff that you have performed an Emergency Quench.

9 Performing a Routine Scanner Shutdown or Reboot

A shutdown or reboot of the MRI scanner initiates a routine electrical shutdown should a situation or problem arise. This takes a few minutes to complete and can be down if any of the following occurs:

1. A notice has been received that there is an electrical outage to the building.
2. There are visible alarms that revealed that the magnet has quenched or that helium levels are low.
3. The scanner table is not responding to controls.
4. An error message has occurred that requires the system to be rebooted.

Shutdown or Reboot Procedure

1. Along the top of the system is a bar of various commands. Select “System”.
2. From “System” <End Session>:
3. Then select either, <Shutdown System>, <Restart System>, or <Restart Application>
 - a. Shutdown System will shutdown the entire MR system.
 - b. Restart System is only used to reboot the system.
 - c. Restart Application is only used to reboot the software. {i.e. 3D, Spectroscopy Tabs not functioning}

10 Infection Control

In general, the center is designed to scan medically stable individuals. If an individual is not feeling well, we strongly suggest that you defer the scan until the participant recovers. Usually, people who do not feel well tend to have a hard time staying still for a scan, and often do not comply well with functional imaging tasks. It is important to avoid spreading infections, so if someone appears unwell clean all surfaces that they contact. Infection control consist of cleaning the scanning table, coil, positioning pads, and the emergency squeeze.

11 Reporting Incidents

All accidents and/or incidents (this also refers to near incidents) must be reported. An accident/incident report form is available from www.cabiatl.com, and this should be submitted to Nytavia Wallace within 24-hours of the event. In addition, these forms will be forwarded to the IRB.