UR CABIN

MR Safety Considerations

MRI has three types of fields: 1. Static magnetic field, 2. time-varying gradient field and 3. radiofrequency (RF) field. There are potential risks associated with each field.

1. Static Magnetic field

The main potential hazard concerning the static field is the missile effect.

Static magnetic fields are magnetic fields that do not vary with time. The static magnetic field is the main magnetic field created by the superconducting coils and is measured in Tesla. 10,000 gauss equals 1 Tesla. The earth's magnetic field is roughly .5 gauss or .05mT. So, a 1 Tesla magnet is 20,000 times stronger than the earth's magnetic field, which makes **our 3T scanner 60,000 times stronger than the Earth's magnetic field!**

There is a stray magnetic field outside of the magnet bore and is known as the fringe field. Superconducting magnets use active shielding which confines the fringe field to the scan room. The perimeter around a MR scanner within which the static magnetic fields are higher than five gauss, is called the **5 gauss line**. This is 10 times higher than the average earth magnetic field. The 5-gauss fringe field affects pacemakers and other devices such as implantable defibrillators, therefore people with these devices should stay out of the area. Fringe fields beyond the 5-gauss line are considered 'safe' levels of static magnetic field exposure for the general public. **At CABIN we consider the threshold of the magnet room door as the 5-gauss line. <u>Electronic devices and ferromagnetic objects are strictly prohibited inside the 5-gauss line.</u>**

The magnetic field of an MR system has the capability to attract ferromagnetic objects (e.g. iron, some stainless steel) towards it with a high velocity and force. The attractive force is proportional to the static magnetic field and the spatial gradient (i.e. rate of magnetic field change with distance), **and is largest near the magnet bore entrance where the spatial gradient is highest.** A paper clip has a terminal velocity of 60mph in a 3 Tesla magnetic field. The larger the object, the greater the velocity and force. Therefore, metal brought into the magnet room becomes a potential lethal weapon!

NOTE! Objects that do not appear to contain any metal may have ferromagnetic metal inside. Non-ferrous metals such as titanium, gold, silver, copper, brass, and aluminum are generally safe to go into the magnet. However, prior to taking any object into the MRI scan room, you should test it with the 1000 Gauss test magnet (shown at right). **Always test and verify!** The test magnet is located just right of the MR console in the control room.

Besides projectile effect, ferromagnetic implants or fragments in the body may rotate or move causing internal injury. Therefore, everyone must be carefully screened prior to entering the magnet room, and any implants participants may have MUST to be checked and approved by CABIN staff. **Anyone inside the 5-gauss line MUST be screened and MUST be accompanied by authorized personnel.** The control room is restricted access only. **DO NOT prop the door open.**

2. Time-varying Gradient Magnetic field

There are two potential physiological effects associated with the gradient magnetic field – peripheral nerve stimulation and acoustic noise.

Gradient coils are a set of resistive wire windings that are used to spatially encode the positions of the information in the emitted signal by varying the magnetic field linearly across the imaging volume. The gradient magnetic field is produced when electrical current is applied rapidly and briefly to the gradient coils during image acquisition. The gradient magnetic field is also referred to as the time-varying field since the strength and speed of the gradients change throughout the imaging process.

Peripheral nerve stimulation
The rapid switching of gradient magnetic fields during image acquisition has the potential of inducing stimulation to the peripheral nerves and contractions to muscles resulting in tingling or twitching sensations. The effect increases with the rate of gradient switching, and is more noticeable in techniques that use fast gradient switching such as EPI (fMRI or BOLD and diffusion weighted sequences).

Acoustic noise
Scanner acoustic noise occurs during the rapid alteration of currents within the gradient coils. The rapid rise and fall of currents within the gradient coils in the presence of the static magnetic field cause strong forces that produce minute expansion and contraction of the coils. This causes the gradient coils to move against their mountings and the vibration of the coils and the vibration of their mountings cause the loud knocking noise. Certain types of pulse sequences such as EPI (fMRI or BOLD and diffusion weighted sequences) and other fast imaging sequences will create a high and potentially dangerous level of acoustic noise of over 100dB. **Therefore, everyone, including deaf subjects, is required to wear ear protection.** Use either disposable earplugs or headphones with disposable covers. Anyone who stays in the scan room during the study is also required to have ear protection.

3. RF field

The potential hazards from the RF field are tissue heating and burns.

During the MR scan, short intense bursts of RF field (RF pulses) are introduced into the subject. The application of an RF pulse flips the proton spins that produce the MR signal and also results in body tissues absorbing energy. The principal effect of RF absorption

on body tissues is the potential for a rise in core body temperature. In addition, focal heating can occur when concentrated RF energy is absorbed by a localized volume of tissue (e.g. near a metallic implant) or when electric current induced by the RF field causes resistive heating (e.g. at skin-to-skin contact point in a body loop). The amount of heating depends on the static magnetic field strength and the type of sequence being used. A high flip-angle (e.g.180°) pulse deposits more RF energy than a lower flip-angle (e.g 90°) pulse. There is more energy deposited using sequences that employ many 180° RF pulses (such as fast spin echo) than those that use fewer and lower flip angle RF pulses (such as gradient echo EPI).

Specific Absorption Rate (SAR) is the measure of the rate of RF energy absorbed in the body (watts per kilogram). The FDA has set safety guidelines for this. MR systems calculate the SAR based on the pulse sequence and the participant's weight and height. For this reason an ***accurate* weight and height** must be entered on the computer console.

RF pulses have the potential to heat metallic implants and neighboring tissues. A subject with unauthorized implants should never be scanned at CABIN. Even an authorized implant may lead to unexpected heating, therefore be sure to warn the subject of the potential for heating and instruct the subject to use the squeeze bulb if any unusual sensation (such as heating) is felt in the area of the implant.

RF pulses also have the potential for burn hazards from electrical current induced in conductive wire or loops. **Therefore, when using any coils be sure that no loops are created by the coil cables, nor allow the cables to touch the subject.** Besides, loops formed by the subject's body, e.g. when a thumb touches a thigh, crossing hands or legs, can also lead to induced current and burn. **Skin to skin contact should be avoided** to prevent the formation of conductive loops. Pads at least 1cm thick should be used to separate conductive cables from the subjects and to separate body parts to prevent skin-to-skin and skin to magnet bore contact. Perspiration/wet clothes can also lead to increase of burn risks. **Room temperature should be 75 degrees or lower and if the scanner's internal fan can be used to keep the subject cool.**

MR Safety Labeling

Devices, implants and other equipment are labelled as MR Safe, MR Unsafe or MR Conditional. **All devices, implants, and equipment must be checked and approved by CABIN staff.**

MR safe items are safe in all MRI environments and conditions.

MR unsafe items carry unacceptable risks to people in the MR environment. **MR unsafe items should not enter the magnet room and subjects with unsafe devices should not be scanned.**

MR conditional items carry no known hazards in specific MR environment under certain defined conditions.

Medical Implants/Devices

For a MR conditional implant or device, the manufacturer specifies MRI safety conditions with respect to static magnetic field, maximum spatial gradient, RF limit (SAR, B1+rms), time-varying gradient limit (dB/dt) and other conditions. These conditions are used as guidelines by UR CABIN to determine whether it is safe to scan the subject with the implant, and if so those conditions will be followed during the MRI.

Subjects with active implants (i.e. devices that require a power source to function, e.g. pacemakers, neurostimulators, etc) are excluded from participation in MRI at UR CABIN.

Equipment owned by Researchers

If your study plans to use equipment that is not already available at CABIN, that **equipment must be checked and approved by UR CABIN before the study begins.**

CABIN MRI Emergency Procedures

Medical Emergency

In case of a medical emergency, call 911. State that you are in the Medical Center Annex Building, 430 Elmwood Ave. and report the nature of your emergency.

Get the person out of the scan room as quickly as possible. There is an MR safe stretcher located in the rear of the scan room if needed. If you need assistance there is an alarm switch located by the scanner door. When you flip this switch, an alarm goes off in the UR CABIN hallway and all available personnel will be there to offer assistance. This alarm stays on until someone arrives to help.

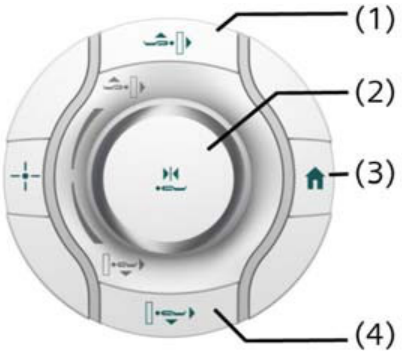
The fastest way for moving the table out of the scanner is to press the Home Position (3).

(1) **Table Up/Inward** button

(2) Jogwheel, **Center Position** button

(3) **Home Position** button

(4) **Table Down/Outward** button



If you need to stop the motorized movement of the table there are two red table stop buttons located at the head end of the table on the side—one on either side of the table. There is also a table stop button located on the intercom in the control room. This is on both sides of the table

Once activated, lights on the front panel of the scanner will flash until you reset the table stop. To reset the table stop, turn the **Table Stop** button clockwise until it releases mechanically. Then simultaneously press the **Table Up/ Inward** and the **Table Down/Outward** button fully.

There is an emergency cart located in the control room behind the door if needed. The equipment on this cart is **NOT** MR safe. You **MUST** get the person out of the scan room first. Be sure to close the scan room door after removing the subject to prevent entry of unauthorized personnel.

Our emergency cart has the very basic items needed for CPR. We have an AED (automatic external defibrillator in the hallway by the elevator and in the control room), portable suction, oxygen tank, ambu bag, suctioning, blood pressure cuff etc. The cart is located in the control room, 1B107A, behind the door. There is a complete listing of items on the lower shelf of the cart.

Subject Communication

The squeeze bulb is a communication device used by the subject for contacting the scanning personnel for any type of emergency or concern. Every subject **must** be given the emergency squeeze bulb and instructed as to how to use it. When the button is pressed an alarm is heard in the control room. Stop the scan immediately. By pressing the talk button on the intercom you will reset the alarm when you to check in with the subject. The squeeze bulb is latex free. Always maintain communication with the subject via the two-way intercom.

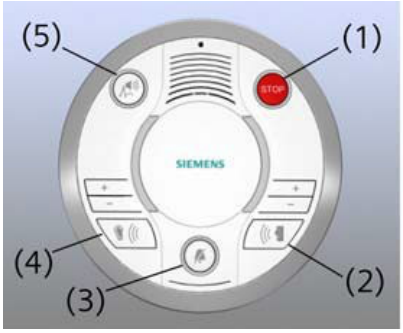
(1) **Stop** button

(2) **Talk** button

(3) **Reset Patient Alert** button

(4) **Listen** button

(5) **Physio Signal** button



To visually monitor the subject there are two cameras aimed toward the subject while in the scanner, and the images are presented on a large LCD screen in the control room. Visual contact must always be maintained during a scanning session.

Fire Emergency in MRI

In case of a fire, follow RACE (Rescue, Alert, Confine, Extinguish). Stop the scan and remove the subject from the scanner. Call 911 and state that you are in the Medical Center Annex Building, 430 Elmwood Ave. There is a fire alarm, which is located on the

other side of the double doors (in the main hallway) just outside of the control room.

If it is an electrical fire (in the scanner or electronics cabinets) press the emergency stop button and pull the tab on the blue box located below the stop button to activate the sprinkler system. Be sure to close doors to contain fire before leaving the building.

We do have an MR safe fire extinguisher just outside of the control room. It is located on the wall opposite the sink. Use this only if the situation is appropriate.

Be sure to advise emergency personnel of the MR system. Local firefighters are aware of the safety issues concerning the magnet but they still need to be reminded and monitored. MRI personnel should be available to warn firefighters of the hazards of the MRI environment and to prevent ferromagnetic equipment from entering into the magnet room. In the event of a fire during off-hours, Public Safety will be responsible for securing the MRI area and assisting fire personnel.

If you smell smoke in the scanner or in the electronics cabinets, remove the subject from the area. If the situation is such that there is no immediate danger, shut down the computer first then press the emergency stop button. Notify Siemens service and directors Madalina Tivarus, John Foxe, Jianhui Zhong in the event of a fire or smoke.

Emergency Shut–off Switches

Emergency stop/shut-down switch (electrical supply only). By pushing this button all electrical supply to the magnet PDU (power distribution unit) is disrupted. It does not initiate a quench. **THE MAGNET REMAINS RAMPED ("ON"). MAKE SURE ALL FERROMAGNETIC OBJECTS REMAIN OUTSIDE OF THE SCAN ROOM.**

Use this if there is a fire or electrical accident in the scan room or the electronics cabinets, or if the sprinkler system goes off in either of these rooms. Also, if you see or smell smoke coming from the magnet or a computer cabinet, use this button. Call UR Security at ext. 13. State that you are in the Medical Center Annex Building, room 1B107 and explain the problem.

There are three of these in the MRI area:

1---inside the scan room, on the wall by the door.
2---in the control room, to the left of the scanner monitor.
3---in the computer cabinet room, on the wall by the door.

Magnet Stop / Quench switch

There are two Magnet Stop buttons: both covered with a plastic flap.

Magnet Stop button

This is located in the magnet room. This panel is located in the control room.

The only time this button can be pushed is if someone's life is at risk. **Only an UR CABIN staff member can push this button**. By pushing this button you rapidly reduce the magnetic field strength. The helium coolant boils off suddenly during this process and is released through an exhaust vent.

An alarm signal will sound when the magnet stop button is pushed.

Since a quench cost thousands of dollars and may damage the magnet, **ONLY quench the magnet if a large metallic object pins or impales a person against the magnet and no other method will free them or prevent further injury**.

Never attempt to pull large metallic objects from the magnet field. The object may change its magnetic polarity and re-align itself on the magnet and become a projectile, causing a serious or fatal injury.

If you need to quench the magnet, remove all personnel from the scan room as soon as possible. It takes about 20 seconds for the magnet to lose its power. Initiating a quench will release the helium through a vent to the outside.

Notify Siemens service and directors Madalina Tivarus, John Foxe, Jianhui Zhong immediately if this button is pushed.

Magnet Quench: Failure of vent

During a quench, the magnet loses its super-conductivity and the liquid helium boils off through an exhaust vent. It takes only 20 sec. for the magnet to quench. When a quench occurs an alarm goes off (which can be silenced on the alarm box) and a hissing noise is heard as the helium is vented outside. Do not attempt to touch the vent during a quench due to the extremely cold temperature. Frostbite will occur. Large

plumes of white fog appear outside as a result of the helium release.

One liter of liquid helium will quickly expand to about 800 liters of gaseous helium. If the exhaust vent fails, whereby the helium is vented into the scan room, it will quickly reduce the oxygen level in the scan room and cause asphyxiation. Frostbite and/or hypothermia may also occur. **Remove the subject from the scan room by staying low to the floor**.

If you need to quench the magnet, remove all personnel out of the room first! If someone is pinned to the magnet, **be absolutely sure that you have propped the scan room door open with the doorstop**. If the vent fails, the pressure caused by the expanding gas will slam the door closed and it will be impossible to open until the pressure of the gas is released. There is a passive vent in the ceiling of the magnet room to help alleviate the gas.

Be sure to notify Siemens service immediately in the event of a quench. Also notify the CABIN directors Madalina Tivarus, John Foxe, Jianhui Zhong.

A copy of these procedures and contact personnel are kept in the control room.