Henry H. Wheeler, Jr. Brain Imaging Center

Safety Training Syllabus and Standard Operating Procedures

Introduction:

The purpose of this course is to familiarize you with the hazards found in the Brain Imaging Center (BIC), and to educate you on procedures in the event of various emergency situations. It is vitally important that you have a full appreciation of the hazards and know how to react appropriately to many different types of dangerous or emergency situations. In addition, scanner users are responsible for the safety of their subjects, as well as any guests or visitors they bring to the BIC, and you must therefore be able to inform these people of the correct protocols to follow while they are in the BIC. The best way to ensure a safe environment is for you to recognize potential dangers and modify your own and other people's behavior accordingly.

Having watched the introductory videos, read this syllabus and attended a live safety training class you will be ready to take the safety quiz. The quiz is based on the material in this document, not on the videos. A passing grade is required in order to attain card key access to the BIC. (Access to any of the MRI suites and use of the MRI scanners is restricted to qualified scanner operators only.) Further information on scanner access policies, operator training and other scanning information is available on this web page:

http://bic.berkeley.edu/scanning

Permanent BIC occupants:

Some parts of this document contain information replicated from the Li Ka Shing Center Building Emergency Plan (BEP). The BEP is mandatory reading for anyone who works in BIC full-time, i.e. if you have an office in BIC. Please contact the BIC manager if you need a copy of the BEP.

Preliminary videos:

You should watch the following four videos before reading the rest of this syllabus. Please note that the videos are introductory only, designed to familiarize you with some of the typical MRI hazards. In the case of any conflicting information, the specific policies and information found in this document shall take precedence.

In the first video, produced by Siemens, you will get an overview of all aspects of MRI safety:

https://www.youtube.com/watch?v=r6d-6WUw3As

We scan volunteer participants rather than patients, but otherwise the safety requirements for a research site resemble those in a clinical imaging facility, as appears
in the video. While the information in the video is generally useful for us, please note that BIC has non-magnetic, MR-compatible fire extinguishers in the MRI suites. (Fire extinguishers in corridors are not MR-compatible.) Also, we don’t scan pregnant (or potentially pregnant) women. You will learn more about other BIC-specific safety issues, suite layout, and our persistent superconducting magnets in the rest of this document.

Next, another introductory video, this time courtesy of GE, in which you will learn more about superconducting magnets:

https://www.youtube.com/watch?v=xefyXb5u658

While this video is a little old, most of the safety information remains true today. Our magnets no longer need liquid nitrogen, only liquid helium, and we no longer rely upon the use of a hand-held permanent magnet to ensure an item is MRI-compatible. It would be too easy to miss a ferromagnetic component buried deep in the device! (BIC staff conducts these checks and we have specific operating procedures for any item that must be brought into the exam/magnet room, as you will learn during your user training.) You will learn more about the circumstances when you may be required to initiate a “quench” of the MRI magnet rather than waiting for expert assistance from BIC staff. Otherwise, all the issues described in the video apply directly to the BIC scanner suites.

The forces demonstrated in the last video were quite dramatic. They used a 1.5 T magnet. Here are some tests that BIC staff conducted a few years ago, as we were getting ready to shut down a 4 T magnet:

https://www.youtube.com/watch?v=6BBx8BwLhqg

When we shut down the 4 T we did so by initiating a quench. Watch how quickly magnetic objects stuck on the magnet fall off as the magnetic field decays:

https://www.youtube.com/watch?v=9SOUJp5dFEg

The helium gas is so cold it freezes the air and creates a plume of white vapor outside. Inside, everything that is in contact with the venting helium becomes frozen, and air liquefies on the steel surfaces. Serious cold burns would result from going near the magnet surfaces after a quench, while the plume of venting gas would destroy lungs, eyes and other sensitive tissues in a matter of seconds.
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1. General Emergency Procedures and Information:

1.1 Contact names and numbers:

**Emergency situations:** Call 911 from any office/campus phone, or contact UC police via cellphone on 510-642-3333

For urgent situations that are not life-threatening, for notifications, and for any questions:

Rick Redfern, BIC Safety Officer:

Office - (510) 643-1655, Cell - (510) 847-3060
E-mail: redbush@berkeley.edu

Ben Inglis, Alternate BIC Safety Officer & BIC Manager:

Office - (510) 643-1655, Cell - (510) 388-8321
E-mail: binglis@berkeley.edu

Jack Gallant, BIC Co-Director:

Cell - (510) 361-9750
E-mail: gallant@berkeley.edu

Chunlei Liu, BIC Co-Director:

Cell – (510) 664-7596
E-mail: chunlei.liu@berkeley.edu

1.2 Emergency information:

Campus emergency information line (for any large-scale emergency):

1-800-705-9998

Campus emergency website:

http://emergency.berkeley.edu

Campus radio station:

90.7 FM (KALX)

The campus warning siren is tested at noon on the first Wednesday of each month. If you hear the warning siren at any other time you should take shelter inside, close doors/windows, and go to one of the information sources listed above to obtain campus emergency information.
UC students, faculty and staff may also sign up for electronic (e-mail or text) alerts from the WarnMe emergency alert service:

https://warnme.berkeley.edu

City of Berkeley emergency information:

https://www.cityofberkeley.info/EmergencyAlerting/

1.3 Medical/first-aid providers:

**University Health Services/Tang Center**

2222 Bancroft Way #4300   (510) 642-3188   (Urgent Care)
Berkeley, CA 94720

8 am to 5 pm, Monday-Friday
9 am to 5 pm, Saturday

**Alta Bates Hospital**

2450 Ashby Avenue   (510) 204-1303   (Emergency Room)
Berkeley, CA 94705

24 hrs, 7 days/week

1.4 Building address and location:

Li Ka Shing Center,
University of California,
Berkeley, CA 94720

The Brain Imaging Center (BIC) is located in the basement level of Li Ka Shing Center (LKS). The Siemens Trio (3 T) MRI operator room is number B100E. The magnet room is number B100EA. The GE 3 T MRI operator room is number B100C, and its magnet room is number B100CA. (See section 1.8 for a BIC floorplan.)

Siemens 3 T operator room phone: (510) 643-1808
GE 3 T operator room phone: TBD

1.5 In an emergency, use a lab phone *(i.e. a land line, rather than a cellphone)* to call 911 if you can. This will allow tracking from the dispatch center if you are unable to provide an accurate description of your location. Otherwise use a cellphone and call the UC Police Department dispatch on (510) 642-3333. Note that cellphone reception can be patchy in the BIC basement, however.
It is recommended that all BIC users have the UC Police Department emergency number programmed into your cellphone. You might also consider adding police department dispatch numbers for Alameda County, Berkeley PD and any other jurisdictions you frequent, e.g. BART, San Francisco.

When talking to the 911 or UCPD dispatcher, try to remain calm and be prepared to give as much information about the emergency as you can, e.g. the nature of the emergency, where the emergency is located, if there are injuries or an imminent threat of injury, etc.

1.6 All accidents and incidents must be reported to the BIC Safety Officer or the Alternate BIC Safety Officer. There are legal requirements for reporting accidents, some of which may affect your personal liability.

1.7 The LKS fire alarm is a chime accompanied by white strobe lights. In the event of a fire alarm it is a legal requirement for all building occupants to evacuate immediately. Upon leaving the building, assemble at the BIC’s designated **Emergency Assembly Area (EAA)** on the paved portion of the Springer Gateway (The Crescent), next to the Campus West Gate, and await instructions from emergency response personnel (fire or police) or the BIC Safety Officer. Do not re-enter the building until instructed to do so by emergency responders.

**Location of BIC’s EAA:**

![Map of BIC's EAA](image)
During a fire alarm or other emergency, building evacuation must be via one of the two stair wells. (See section 1.8 for locations.) The elevator cannot be used in an emergency. In the event of a fire alarm, the elevator car will be summoned automatically to the entry floor level (which is the upper level as far as BIC is concerned) and will remain inactive until the alarm is cleared and the building elevators are reset by the emergency services.

1.8 There are two emergency exits for BIC occupants: (i) the stair well adjacent to the BIC elevator (bottom right in the figure below), and (ii) through the door at the end of hallway B100 (top left in the figure below):

The B100 hallway door (top left in the above figure) leads to a dedicated emergency exit corridor that takes you up to the surface via a set of stairs. The surface level door opens to the driveway between Barker Hall and Li Ka Shing Center.

Once through the B100 emergency exit door, turn left and follow the corridor until it ends at the surface level. There is only one way you can go. If you turn right after going through the B100 door you will encounter a locked door which is an emergency exit from another facility. Turn around and keep moving until you encounter stairs up and then the door to the outside.
The B100 emergency exit door is not locked in either direction so if you find that your exit is blocked you can return to the B100 hallway and take the exit in the BIC lobby, adjacent to the BIC elevator, instead. Note, however, that the B100 emergency exit door and the outer door at the top of that dedicated corridor are both alarmed and monitored by video surveillance. Use of the B100 emergency exit door is permitted in an emergency only. Use of this exit path for any other purpose is subject to investigation by UC police, and may result in suspension or cancellation of access privileges to LKS.

1.9 Individuals with mobility impairments who are unable to use the stairs should proceed to the Designated Waiting Area (DWA), next to the BIC elevator (at the foot of the entry/exit stair well) to await emergency responders.

If your subject/visitor has a mobility impairment and you are unable to assist them to evacuate via a stair well, accompany the person to the DWA and then evacuate the building yourself. Upon reaching the EAA, notify either the BIC Safety Officer or an emergency responder of the location of the individual(s) within BIC, or notify rescue personnel by phone – (510) 642-3333 if using a cellphone, or 911 via a land line - of the location of the individual(s) requiring assistance.

2. Electrical hazards:

2.1 Be careful with liquids in the vicinity of all electrical equipment in the BIC. There are a lot of power leads for all the stimulus peripherals!

2.2 During a power failure the magnet and operator rooms are designed to have emergency lighting, which should turn on (perhaps after a brief outage or a flicker) once a backup generator comes online. In the Siemens 3 T suite, additional emergency lights have been added inside the window space between the operator room and magnet room.

In the event of a blackout and you need to use a flashlight (or the flashlight feature of your mobile phone) to see in a magnet room, don’t carry the flashlight inside because it likely has magnetic components! (The magnet will still be on!) Instead, place the flashlight on the operator console desk, shining through the window into the magnet room.

If the power stays out, remove a subject from the magnet manually, e.g. by disconnecting the top sled of the patient bed and retracting it, or by pulling the subject out gently by his/her feet. In the case of a ‘brownout’ (a power fluctuation where the power comes back on) it is safe to restart the scanner and continue with the scanning session, assuming you know how to bring the scanner back online.

2.3 If you need to disable electrical power to the scanner, gradients or patient bed in an emergency, push either one of the red wall-mounted buttons labelled
EMERG
ENCY
POWER OFF. Pushing these buttons disables power to the patient bed and the entire scanner electronics, including the gradient coils and the helium refrigeration unit (the unit that keeps the magnet cold). Note that this button does NOT disable the magnet! The magnetic field will stay on!

Should you need to use the EMERGENCY POWER OFF button for any reason, you will need to contact BIC staff to get the scanner restarted. You should notify BIC staff immediately because the magnet refrigeration unit should not be left off for an extended period of time. After a few hours, the magnetic field is liable to drift, which affects performance, and there is an increased risk of the magnet quenching if the refrigeration is off for more than a couple of days.

2.4 MRI gradients are water-cooled. The cooling water is in electrical contact with the internal conductive surfaces of the gradient windings, meaning that the water inside the gradients is conducting a very high electrical current. Therefore, in the event of a water leak at or near the magnet there is the possibility of receiving an electric shock from coming into contact with the water. As a general rule, then, you should assume that water found in or near the magnet is dangerous and should not be touched.

If water is found in or near the magnet you should remain outside the magnet room and place a note on the magnet room door to notify other users not to enter. Do not attempt to use the scanner! Contact BIC staff for instructions on how to proceed. If you like you may power the scanner down using the EMERGENCY POWER OFF button as described in section 2.3 before contacting BIC staff.

If someone receives an electric shock from coming into contact with water in or near the magnet, immediately disable the power using the EMERGENCY POWER OFF button.

3. Fire hazards:

3.1 The most likely ignition sources in the BIC are: (i) electrical ‘shorts’ or overheated electronics, including within the scanner itself, and (ii) items brought into the operator’s room by users, subjects and visitors, e.g. cigarette lighters.

3.2 A manual fire alarm is located in front of the BIC elevator, next to the entry/exit stair well. There is an additional manual alarm in the emergency exit corridor beyond the doors at the end of the B100 corridor. (See the floorplan in Section 1.8.) Smoke detectors in the ceilings of the corridors, the operator rooms and the equipment rooms are connected to the building fire alarm system and should activate the fire alarm automatically. Magnet rooms have a heat sensor to trigger the fire alarm.

The Siemens 3 T has a retrofitted set of smoke detectors that monitor the gradient connectors at the rear of the magnet, the gradient filter box in the wall behind the magnet, and the room air immediately behind the magnet. These
detectors will shut off the electrical supply to the scanner automatically. They do not, however, trigger the building fire alarm.

3.3. The procedure to follow in the event of a fire in the BIC is, first and foremost, dependent upon whether the fire alarm has activated automatically or not:

- If the fire alarm has not yet been activated automatically, you should recover a subject from the scanner and evacuate immediately, as described in sections 1.7 and 1.8. Activate the building fire alarm manually as you exit. (See section 1.8 for manual fire alarm locations.) Do not return to the fire once the alarm is sounding; continue with your evacuation.

- If the building fire alarm has already activated automatically then you may choose whether it is safe to attempt to fight a small fire with a fire extinguisher. Whether or not you tackle the fire, and whether or not the fire is extinguished, you must then evacuate the building.

If the fire is located in a magnet room or MRI electrical equipment room then it is prudent to assume that the source of the fire is the scanner itself. It would be useful to shut off power to the scanner using one of the EMERGENCY POWER OFF buttons. However, your main focus should be raising the alarm and evacuting the BIC.

3.4 If the fire is small, it is safe for you to do so, and if you have received training on use of a fire extinguisher, you may consider using a fire extinguisher to fight a small fire, but only if the fire alarm has already been activated. MR-compatible fire extinguishers are located in magnet rooms (Zone IV – see section 5.2) and in the operator's rooms (Zone III – see section 5.2).

If the fire seems to be located inside the scanner itself, e.g. at the rear of the magnet (where the high power cables connect to the gradients), or is located in the electrical penetration panel in the wall behind the magnet (where the high power cables exit the magnet room to the equipment room), then use of a fire extinguisher is unlikely to help, because the fire may be concealed behind a cover that prevents the fire-retarding agents from working. Instead, you should disable power using the EMERGENCY POWER OFF button, then evacuate.

Don’t do anything that would put you or someone else at risk. If in doubt, evacuate the building and wait for the emergency services.

4. Sudden or unexpected magnet quenches:

4.1 Violent vibrations caused by an earthquake, or the impact of a large magnetic object hitting the magnet (see later), may result in a magnet quench. The electrical energy which is flowing around the superconducting wire – creating the magnetic field – is dissipated as heat via any points in the wire that have become resistive.
When a superconducting magnet quenches, the liquid helium that keeps the magnet cold will vaporize over a few tens of seconds. The volume of gas that results is about 700 times that of the liquid, causing a large plume of freezing gas to emerge from the magnet at high velocity through a specially designed quench duct in the ceiling above the magnet that vents to the outside of the building. The volume of gas would be about 2 million liters! Its temperature would be less than $-250$ deg C. At the same time, the magnetic field will decay from 3 T to zero.

4.2 There is a risk of asphyxiation and/or burns from the ultra-cold helium gas. The gas should exit the building through the quench duct. However, it is best to assume the vent may fail - perhaps it has become blocked, or a joint fails because of the intense cold and vibration - causing deadly cold gas to enter the magnet room. Air coming into contact with the cold helium gas will freeze instantly, as would skin, eyes, lungs, etc. Just in case, then, it is best to assume the quench duct may fail and to evacuate the magnet room as quickly as possible. Evacuate at least as far as the corridor outside the operator’s room, but move farther away if you see any white vapor in your vicinity.

4.3 Magnet quenches occur very rapidly. It will take no more than about 30-40 seconds for the magnetic field to decay to zero. By the time you realize what is happening, the quench may be almost over. You may feel or hear low rumbling coming from the magnet but, like small earthquakes, it takes time to determine the source of the noise or the shaking.

If you think the magnet is quenching, you should commence evacuation. In case there is helium gas escaping into the magnet room, you should first open the magnet room and operator room doors and prop them open, to prevent a pressure build-up. Then, if you can do so safely, go into the magnet room (ensuring that the magnet room door remains wide open) to remove the subject from the magnet as quickly as possible.

It is dangerous to re-enter the magnet room after a quench. If helium gas has leaked from the quench duct, it may have displaced most or all of the oxygen in the room. Without sufficient ventilation the oxygen level may remain very low for hours after a quench. Do not re-enter the magnet room after an actual or suspected quench until you are cleared to do so by a member of BIC staff.

4.4 The oxygen level in the magnet room is monitored remotely, and a low oxygen condition will trigger an alarm in the building management system. Since an appropriate response to such an alarm cannot be guaranteed, an additional oxygen alarm has been installed in the B100 corridor to monitor both 3 T scanner suites. In the event of a low oxygen alarm when you are in one of the 3 T MRI suites, you should immediately open both the operator room and magnet room doors and evacuate as if a quench is occurring.

If you enter BIC to find the oxygen alarm has been activated, do not attempt to enter either 3 T scanner suites! Do not proceed! Evacuate immediately, contact BIC staff and do not re-enter BIC until cleared to do so by staff.
5. Magnetic field hazards:

5.1 Nobody shall enter a magnetic field region greater than 5 Gauss (G) (0.50 millitesla, mT) without first having been thoroughly checked for magnetic items and screened for any health hazards associated with high magnetic fields. In particular, cardiac pacemaker wearers are prohibited from entering a magnetic field of 5 G or higher, unless explicitly cleared to do so by appropriate medical professionals.

The 5 G contour is approximately elliptical about the magnet, as indicated by dashed red lines in the figure in section 5.2, below. In the Siemens 3 T suite, the 5 G contour extends to the front wall of the magnet room. The contour falls in the middle of the concrete shear wall, at about the position of the magnet room window, but does not project into the operator room. At the rear of the magnet, however, the 5 G contour falls inside the scanner’s electrical equipment room. (For comparison, note that the earth’s magnetic field is approximately 50 µT so the 5 G (or 0.50 mT) fringe field contour represents the point at which the magnetic field intensity is ten times greater than a person experiences routinely.)

To ensure safe operation and screening, BIC follows the zoning recommended by the American College of Radiology (ACR). Zone restrictions are given in section 5.5.

Because MRI magnets are actively shielded, the initial magnetic field you experience on entering the magnet room is fairly low; probably too low for you to feel on your belt buckle or on the screwdriver you’ve absentmindedly carried in with you. However, the magnetic field increases VERY rapidly as you approach the magnet. You may not feel the magnetic field’s effect on a magnetic item until you are near the patient bed, by which point the item will probably be pulled from your hands! Magnetic items are therefore prohibited in the operator and magnet rooms, as explained in section 5.5.

5.2 Each room or corridor in BIC is categorized as belonging to one of three zones, as indicated on the floorplan below:
Zone I – This is not depicted because it is a conceptual zone that encompasses the outside world; that is, everything outside of the BIC elevator and the entry stair well. Once inside BIC space you are in Zone II or above and you must adhere to the following restrictions and procedures at all times:

Zone II – BIC secure area

Only persons who have passed the BIC safety certification may have unsupervised access to Zone II. Card keys for access will be activated only for persons who have passed the safety certification. **All other people, whether staff, visitors or research subjects, must be accompanied at all times by someone with safety certification.** Do not allow unsupervised BIC access to anyone you do not know for a fact has his/her own BIC card key approval to at least Zone II level. If in doubt, ask for verification and/or insist that a person unknown to you uses his/her own card key to gain access. Do not allow people to follow you into the elevator or down the stairwell without first checking their access status. (See also Section 8.1 Intruders.)

Zone III – Screened “magnet safe” area
In addition to the restrictions imposed in Zone II, only persons who have been suitably screened for access into a high magnetic field environment are permitted to enter Zone III. Pacemaker wearers are excluded from Zone III without the express permission of the BIC director or the BIC manager.

Only fully qualified scanner operators – those who have passed user training certification – may have card key access to Zone III (and hence to Zone IV beyond). Trainees are restricted to unsupervised access of Zone II, and supervised access to Zones III and IV with the approval of a fully qualified scanner operator having Zones III/IV access privileges.

Magnetic items, including magnetic chairs, tools, equipment and office supplies (such as scissors) are restricted in Zone III. Only those items approved by BIC staff and properly labeled may be taken into Zone III. All other items will be confiscated.

Zone IV – High magnetic field: Researchers and accompanied subjects only

In addition to the restrictions imposed in Zones II and III, access to Zone IV – the magnet room – is restricted to persons who have been fully screened for MRI contraindications and who are completely free of all magnetic objects on their person. Equipment required for use in Zone IV is subject to review by BIC staff and requires a written standard operating procedure (SOP) before it is permitted. Any item that is not already labeled as MR safe or that does not have a written SOP in the BIC SOP file is prohibited from Zone IV. If in doubt, assume an item is prohibited and consult a BIC staff member. (See section 5.8.)

5.3 Any iron-containing object, including all types of steel (even ‘surgical-grade’ stainless steel), should be assumed to be magnetic. We consider all forms of steel to be potentially magnetic because we usually do not know its history. Dropping a piece of non-magnetic steel on a concrete floor can render it magnetic, for example.

Certain other metals such as nickel, a common coating on electronic components, also exhibit "ferromagnetism." Most batteries contain magnetic components.

Magnetic objects commonly found in the lab, or on people entering the lab, include: flashlights, cellphones, work tools, scissors, ring binders, retractable ballpoint pens, sunglasses, paper clips, calculators, keys, chairs, brooms, shoes (rivets and eyes for laces, and sometimes toecaps), belt buckles, hair clips, and even "aluminum" ladders which use steel rivets, and wooden stools which use steel screws! In fact, once you start looking for magnetic parts you’ll quickly find that most common items have some amount of ferromagnetic metal in them.

Magnetic objects on casters (wheels) – such as chairs – are particularly risky objects near high magnetic fields. Don’t take chairs into the magnet room! The
chairs in the 3 T operator rooms are actually MR compatible. Just in case, however, it is forbidden to take ANY wheeled chair into Zone IV, whether it is supposedly MR compatible or not.

When a magnetic object encounters a magnetic field it will experience two types of motion. First, it will experience a torque – a twisting force - and try to orient itself such that its longest magnetic axis is parallel to the field direction. Second, if it experiences a magnetic field gradient, the object will tend to move towards the higher field region, i.e. it will accelerate towards the center of the magnet. It will continue to accelerate until it reaches a homogeneous field region, i.e. the center of the magnet.

The speed attained by an item on its journey to the magnet center depends on many factors, including the object’s mass and shape. But speeds can easily exceed 70 mph almost instantaneously. In fact, the speed can be so high that a magnetic object may have sufficient momentum to pass through the magnet and continue towards the magnet rear, even exiting the rear of the magnet briefly before being sucked back in! Most objects oscillate between the poles (ends) of the magnet until friction with the air and frequent impacts with the inner magnet surface degrade the momentum.

People have been killed after being struck or crushed by a magnetic object attracted onto/into an MRI magnet. Other people have been very seriously injured. Objects that are too large to enter the magnet bore will come to rest on the face of the magnet where, although stationary, they continue to exert massive forces. The object will likely crush anything or anyone with the misfortune to be between it and the magnet. Forces in excess of 2,000 lbs (or one ton!) were measured on a standard office chair stuck on the front of a 4 T magnet. If you were the subject on the patient bed at the time, it would be equivalent to being hit by a car. Serious injury or death is all but assured.

You should also be aware of the effects of the magnetic field on other equipment. Most electronic devices respond poorly to high magnetic fields and will malfunction - often permanently - in a field greater than about 20 G. For example, micro-switches and relays can "stick" open or closed in such magnetic fields. Analog watches will stop and possibly break in a high magnetic field. Magnetic "swipe" strips found on credit cards, phone cards, ID cards and BART tickets will be wiped above about 50 Gauss. (That’s not particularly dangerous, but it is annoying and could be expensive for you to replace.) Leave your laptop, wallet, watch, keys, spare change, cellphone and sunglasses in the appropriate operator screening area.

5.4 Non-magnetic (non-ferrous) metals include: gold, silver, platinum, titanium, aluminum, copper, brass and lead. However, it is often difficult or impossible to guarantee that all metal in an object is non-ferrous (and therefore non-magnetic). Extreme care must be used when testing objects for ferromagnetism that a false negative result isn’t obtained. An item may contain a ferromagnetic component that is too far away from external surfaces to be detected by a cursory examination. For this reason, nothing should be taken into the magnet room.
without the permission of BIC staff. You will be informed of the procedures to follow for the specific item you wish to take into Zone IV. (See section 5.8.)

When a non-magnetic metallic object is moved through a high magnetic field it will experience a force that may feel like (ferro)magnetism. But this is actually an induced magnetic field generated by the electric fields set up in the metal because of the motion. (Metals are excellent electrical conductors.) The electric field, and hence the resistance you feel, only persists while the object is being moved. The magnitude of the force is dependent on the velocity of the object. Moving conductive objects slowly through a high magnetic field will minimize the force. When a non-ferrous magnetic object is stationary, there is no magnetic force on it, in stark contrast to a (ferro)magnetic object which will experience a large force even when stationary. [Optional: If you want to learn more about the effects of magnetic fields on moving conductive bodies, search online for articles on the “Lenz effect” or “Lenz’s law.” You may also get a chance to experience the Lenz effect for yourself when you attend the safety training course.]

5.5 Nobody may be permitted to enter a magnetic field greater than 5 gauss without proper screening for internal health hazards. Cardiac pacemaker wearers are prohibited from entering the operator room (or any Zone III or IV space) without the explicit permission of either the BIC manager or the BIC director.

People with surgical remnants/implants in critical organs or in soft tissue (brain, spinal cord, eyes, heart, lungs), must not be allowed to enter the magnet room (Zone IV) regardless of whether the metallic implant/object is magnetic or not. Common implants/objects include: metallic aneurism clips, Harrington rods along the spine, metal flakes in eyes from machine-shop work, deep-brain stimulators for Parkinson’s disease, and bullet or shrapnel fragments. Even when the implanted object is non-magnetic, there is a risk of movement of the object through surrounding soft tissue, causing internal bleeding or other damage. (See section 5.4 for an explanation of the forces experienced by a non-magnetic metal.) Similarly, persons having had recent (less than six months) non-magnetic surgical implants into bone (e.g. titanium pins in a knee or arm) should be excluded until a doctor can confirm that the bone unions are fully formed. (Union typically takes 3 months or more from surgery.) Finally, persons with prosthetic limbs must be able to remove the limb safely prior to entry into the magnet room.

5.6 It is important to recognize that there is no single protocol to follow if a magnetic object impacts or enters the magnet. Each situation must be quickly but carefully evaluated before any action is taken.

First of all, determine whether there is any danger of serious injury or death caused by the object. If there is, immediately push the magnet quench button to discharge the magnetic field. In the Siemens 3 T suite, a quench button is located on the wall to the left of the operator’s desk. A second quench button is located inside the magnet room doorway, on the left as you enter the magnet room. In the GE 3 T suite, there is a single quench button located on the right of the door as you enter the magnet room. The location and proper use of these buttons will be explained during the safety training course.
Pushing the quench button activates a ‘controlled’ magnet quench, which runs the magnetic field down over about half a minute. The field drops exponentially, so you should be able to initiate recovery of your subject within 10-15 seconds. Once you have removed the subject from the magnet you should evacuate BIC in case there is a helium gas leak in the quench vent. (See sections 4.2, 4.3 and 4.4 for the dangers of helium gas produced by a magnet quench.) Seek whatever medical assistance you need by calling 911 from the lab phone.

If there is no immediate danger of serious injury or death, take a few moments to consider your options. If an object is stuck to the outside of the magnet and it is not impacting the subject or preventing egress, determine whether you can remove your subject from the magnet without moving the object, then call BIC staff for assistance. But do not do anything that places the subject at further risk! For instance, do NOT use the patient bed controls if you think that moving the bed might also move the stuck object.

Once all persons are removed from the magnet and there is no further danger to people, you should evacuate the magnet room. Do not allow anyone near the magnet! Do not attempt to remove the object yourself! This may result in injury to you or damage to the magnet. Place a note on the magnet room door stating that the room is off limits to all persons, and immediately call BIC staff for assistance.

What if the object goes into the magnet and comes to rest against the magnet bore? If possible, remove the subject from the magnet but do not do anything that could move the object! For example, you may be able to pull the subject along the patient table without moving the table or the RF coil. If the object is impacting the head RF coil, pull the subject out by his feet instead of using the patient bed controls. This will leave the head RF coil – and the magnetic object stuck to it – where it is.

Why not just push the quench button whenever anything gets sucked into the magnet? If all went well, it would take tens of thousands of dollars and a couple of weeks to bring the magnet back up to field. And that assumes something hasn’t broken during the quench. (Quenching a magnet always brings the risk of catastrophic failure of some vital part of the magnet’s internal components.) A broken magnet could take six months and a million dollars to replace. Therefore, it is critical that you are able to determine the precise injury risks and only then decide whether it is prudent to de-activate (quench) the magnet.

If you do manage to get something magnetic sucked into/onto the magnet, the golden rules are:

1. Think first, then act.
2. Do not try to move (or retrieve) a stuck object. You will almost always make a bad situation worse. (And remember, using the patient bed may well move the stuck object!)
3. Push the magnet quench button if there is a risk of serious injury or death.
5.7 Different people have different sensitivity to high magnetic fields. Some people report feeling slightly dizzy when they move their head inside a high field. Others report a metallic taste in the mouth, an effect which has a neural origin; it has nothing to do with any dental work you may have.

Minimize your risk of feeling dizzy by moving slowly in and around the magnet. You want to reduce the rate of change of magnetic field by slowing your motion. Also, try to move along the axis of the magnet as far as possible, rather than across it. Don’t shake your head inside the magnet bore unless you want to make yourself dizzy!

Other than these slightly bizarre sensations there is nothing inherently dangerous going on. You will probably find that your senses get used to being around the magnet.

5.8 All items taken into Zone IV must be pre-approved by BIC staff. Review and approval involves determining whether the item is a risk to people in Zone IV, whether the item must be labeled (certain items, such as the foam pieces used to restrain a subject’s head inside the MRI coil are exempted), where the item is to be stored, and whether a written procedure is required for its use.

Items that require labeling are marked according to the scheme shown in this chart:

<table>
<thead>
<tr>
<th>MR Safe</th>
<th>MR Conditional</th>
<th>MR Unsafe</th>
</tr>
</thead>
<tbody>
<tr>
<td>‘an item that poses no known hazards resulting from exposure to any MR environment. MR Safe items are composed of materials that are electrically nonconductive, nonmetallic, and nonmagnetic’ *</td>
<td>‘an item with demonstrated safety in the MR environment within defined conditions. At a minimum, address the conditions of the static magnetic field, the switched gradient magnetic field and the radiofrequency fields. Additional conditions, including specific configurations of the item, may be required.’</td>
<td>‘an item which poses unacceptable risks to the patient, medical staff or other persons within the MR environment.’</td>
</tr>
</tbody>
</table>

MR Environment

‘the three dimensional volume of space surrounding the MR magnet that contains both the Faraday shielded volume and the 0.50 mT field contour (5 gauss (G) line). This volume is the region in which an item might pose a hazard from exposure to the electromagnetic fields produced by the MR equipment and accessories.’

Last updated: 8th Feb 2021 by BA Inglis
Note the color coding. Some labels in BIC are printed on a label maker. A red colored label always indicates that the item to which it is affixed is MR unsafe. Labels marked MR conditional (yellow) or MR safe (green) may be taken into Zone IV only after approval by BIC staff, who will advise you on the restrictions to obey and whether a written procedure is required. Otherwise, any item that is not already in Zone IV and is not labeled MUST be considered to be MR unsafe. Consult with BIC staff for further instructions.

6. Hazards of an MRI experiment to the subject:

Note: The information in this section is introductory only. Persons undergoing scanner operator training will receive additional training on subject safety and screening procedures.

6.1 Subjects must have been pre-screened according to the terms of UC Berkeley’s institutional review board, called the Committee for the Protection of Human Subjects (CPHS). The specific screening process you follow will be approved as part of your study, and during operator training you will learn in detail what you should look for from a subject safety perspective. What appears below is a general introduction only. It does not constitute sufficient training to become a scanner operator.

You should start your screening process well before the subject arrives for a scan. Not only does this help protect the subject, it also may save you time. Catch obvious items such as recent surgical events, implanted metal and so on with a pre-screening process well before the day of the scan. You must still screen your subject when he/she arrives at the BIC for these very same contraindications, to assure that he/she is still safe to be scanned.

On the day of the scan, ask the subject to remove all external metallic objects as far as possible. Double check for jewelry, especially pierced jewelry, hair clips, keys and items in pockets. Ask the subject whether they have any metallic implants or have had any recent surgeries or accidents that might have left metallic remnants in their body. If there is even the suspicion of a positive answer to questions concerning implanted metal objects, you must seek specific approval for this subject from a medical doctor before this person can be scanned.

You may wish to screen a subject for metal using a hand-held ("wand" style) metal detector, or using a walk-through metal detector. While this can be a useful process, do not assume that a beep-free scan proves the subject has no metal in or on him! Do not substitute a metal detector screen for extensive questioning! Treat it as an optional extra.

After screening for the Siemens 3 T scanner, use the ferromagnetic detector in Zone III to double-check for any ferrous items that might have been missed in the initial screening. Assuming no contraindications, it is then permissible to allow the subject to access Zone IV. After screening for the GE 3 T scanner, use the walk-
through metal detector to double-check for any metallic items that might have been missed in the initial screening.

Women who are or who may be pregnant must not be scanned. Insufficient research has been conducted on the potential hazard of 3 T MRI to warrant the risk for non-clinical scanning. Per your CPHS-approved protocols, you should (if needed) have female subjects take a pregnancy test.

6.2 While no studies have found any damaging biological effects caused by a static 3 T magnetic field, there are certainly effects such as dizziness and claustrophobia that can have profound physical effects on a subject, and which could be hazardous to them in extreme cases. You should reassure a subject that MRI is a safe procedure, but don't force the issue if they feel extreme dizziness or stress. There is a risk that the subject could experience a panic attack or even a seizure, which could result in serious injury within the confines of the magnet bore.

When first aligning a subject on the patient table you need to instruct the scanner's software on the position you wish to send to the magnet center. On the Siemens 3 T, this procedure involves the use of a red laser light. While intentionally not a strong laser, the light is sufficient to damage a subject's eyes. You should instruct your subject to close his/her eyes before you turn on the laser, and to wait until after the laser is turned off before you permit them to reopen their eyes. You may wish to shield the subject's eyes as an extra precaution.

6.3 When the scanner is acquiring images, the radiofrequency (RF) oscillating (120-130 MHz) magnetic field generated by the transmission RF coil causes a small amount of energy to be deposited as heat into a subject lying in the magnet. The transmission RF field is produced by a body-sized coil which runs the entire length of the magnet. (The coil can't be seen from the outside, it is hidden behind the bore liner of the magnet.) During a scan an estimate of heating is done based on the subject's weight (as given in the patient registration step). Assuming the person has normal physiology, this specific absorption rate (SAR) monitor will assure that the heating effect is kept within safe, regulated limits. Note, however, that the SAR monitor assumes there is no focal heating, as can happen with certain tattoos or pierced jewelry, for instance. Metal jewelry is highly electrically conductive and can provide a convenient 'sink' for the RF power. So, even if a scan can be run safely according to the RF monitoring software, it does not mean there is no burn risk to the subject! More information on the burn risk of tattoos and piercings is covered in the subject screening documentation, which comprises part of the operator training syllabus.

A side note on RF safety and burns. While it is not expected to be a problem for large volume coils such as the body RF coil used most of the time on 3 T scanners, users should be aware that there is the possibility of focal heating (or surface burns) if the subject's skin is placed too close to, or touches, the copper conductive elements of a transmitting RF coil. There should never be exposed components of an RF coil or its cabling. Do not use a coil if you see a worn or broken cable. Notify BIC staff immediately.
Some modern types of clothing can contain tiny metallic particles. They are generally marketed as “anti-bacterial” clothing although the labeling varies considerably. As a general rule, however, it is unlikely that the clothing will have a label stating its constituents fully and it is difficult or impossible to determine by inspection whether the clothing has metallic particles as part of the fibers. For this reason we encourage all subjects to wear natural fibers – usually cotton or wool – for the MRI scan. If such clothing is unavailable, or you are unable to determine whether an item of clothing might contain metallic particles, have the subject change into cotton scrubs (supplied by BIC) for the scan.

Finally, if you wish to scan very young or very old subjects, subjects with very poor vascular health, or subjects who weigh less than 100 lbs, you should talk to the BIC manager before you start. The scanner can be set up to provide an additional margin of safety for persons likely to have low perfusion, or who might be sensitive to slight rises in body temperature.

6.4 MRI uses pulsed linear field gradients (commonly referred to as simply "the gradients") to encode spatial information into the signals being excited and detected. All imaging sequences use pulsed gradients. Fast imaging sequences, such as echo planar imaging (EPI) as used for functional MRI, use gradients that are pulsed very quickly. Furthermore, this gradient pulse doesn't occur in isolation, but with several hundred similar pulses over the course of a second or so. The net effect is that the switching field gradients set up induced electrical currents inside the subject's body. Fortunately, the threshold necessary to generate such effects as peripheral nerve stimulation (PNS) is fairly high relative to the size of the electrical currents being induced, and to date most reports have been limited to tingling or muscle twitches and, very rarely, visual flashes (magneto-phosphenes being triggered in the eye).

As with RF heating, the scanner software monitors the gradient switching and makes estimates of the likely limit that might cause peripheral nerve stimulation. Based on the subject's weight, approximate body dimensions are estimated and used to determine whether the scan is likely to trigger stimulation or not. If the estimate is above a threshold the scan will not run. Note, however, that this is all done by estimation; the only measurement being done is of the gradients themselves. The scanner can only estimate the subject's tissue conductivity and geometry. A subject might still experience localized peripheral nerve twitching without any warning being offered by the scanner.

To minimize the possibility of PNS, you should instruct your subjects to lay in the magnet with their hands by their sides and with their feet uncrossed. This minimizes large current loops around the body. If a subject experiences discomfort during the scan, they should alert you via the squeeze-ball and you can abort. However, it is generally not a good idea to describe in detail all the ways the subject might feel discomfort because there have been many instances where the subject has misinterpreted the vibration of the patient bed for muscle twitching. That said, do make sure the subject is confident you will stop the scan if he or she feels at all uneasy or uncomfortable! It is also safe to proceed with a
scan in which the subject feels twitching, if the subject is happy to continue and if you are confident the subject won't be unduly distracted from an fMRI task.

6.5 The second effect of the pulsed gradients is more easily recognized: acoustic noise from the strong Lorentz forces occurring inside the gradient coil. Whenever a current is passed through a wire that is located in a magnetic field, the wire will try to move in a perpendicular direction to the current and magnetic flux directions. (You may recall Fleming's Left Hand Rule from high school physics.) The higher the current and the larger the magnetic field, the larger the motion. So why doesn't the gradient coil simply fly out of the magnet when it is pulsed? The answer is that it would, were the forces not balanced so that the force trying to eject the coil from the front equals that acting in reverse.

What's more, the wires that comprise each gradient coil's windings are also experiencing their own localized attempts to move. The reason an individual copper wire doesn't fly off the coil is because the whole coil is "potted" in a tough epoxy resin. The sum of all these attempts at motion is the familiar, and extremely loud, "banging" or "pinging" sound that emanates from the magnet during a scan.

It is essential that all subjects be properly fitted with earplugs prior to entering the magnet. Anyone who will accompany the subject in the magnet room during the scan must also be fitted with earplugs. To fit earplugs, squeeze and roll the earplugs along their full length (not just the tip), pull the earlobe slightly backwards and insert the plug almost all the way to the ear canal. Hold in place until the plug inflates over about thirty seconds; the user will hear the gradual muffling of the external noise as this is happening. Only the very end of the plug should be visible outside the ear canal. The more it is in, the better the noise blocking.

If possible, fit your subjects with headphones as well as earplugs. These allow easy communication with your subject as well as additional scanner noise protection. If it is not possible to fit headphones inside the RF coil, consider placing foam padding over the subject’s ears as a secondary noise-attenuating device.

To minimize the sound reaching the operating room, and to maintain the integrity of the RF shielded room that prevents external interference with the MR measurement, it is imperative that the magnet room door be kept closed during all MR scans.

7. Earthquake risks:

(See also section 4 for magnet quench risks.)

7.1 An earthquake could cause many of the hazardous conditions listed previously, with fire, power outage, and a magnet quench probably the most likely. There is also the specific hazard associated with moving or falling objects during violent
shaking. To minimize risk, all peripheral equipment brought into the BIC for experiments must be properly restrained to prevent it from falling during an earthquake. Pay particular attention to heavy objects in cupboards and on shelves.

7.2 Take as much cover as you can during an earthquake. Move away from windows and any high objects, such as cupboards and shelves. Use a nearby sturdy object, such as a desk or a doorknob, for cover and brace yourself against the object until the shaking stops. Bear in mind that the wall between the Siemens 3 T operator room (room B100E) and the magnet room (B100EA) is a seismic shear wall; thus, any building motion is likely (but not guaranteed) to be larger away from this wall. Likewise, both the Siemens and GE 3 T magnets are bolted to the concrete floor and a magnet's steel cryostat is extremely strong. Thus, from a physical perspective, i.e. setting aside the quench risk, the magnet should provide good shelter from falling debris. Do bear in mind that the quench duct above the magnet is connected to the magnet room wall as well as to the top of the magnet, and differential motion of the walls of the room from the floor under the magnet may cause the quench pipe to be compromised, or even fully disconnected from the magnet.

If you feel an earthquake during a scan you should abort the current scan and retrieve your subject from the magnet. Do so even if the scanner power and all peripheral equipment remain on and operational. Evacuate from Zones III and IV and contact BIC staff for further instructions.

In case of a larger earthquake you should assume that there will be a magnet quench, and evacuate promptly. If there is no light when the shaking stops, follow the blackout procedures in section 2.2 and remove the subject from the magnet, then evacuate from Zones III and IV immediately. If you hear any sort of rushing noise from the magnet, assume it is already quenching and make sure you prop the operator room and magnet room doors open as soon as possible. Otherwise, leave the scanner on and evacuate the building then go to the EAA.

If it is safe to do so, on your way out of the BIC check that there aren't any more immediate hazards that have been generated by the earthquake. For example, you might spot an electrical short (e.g. sparks) in a piece of equipment which could become a fire, or a fire already in progress. You may consider taking whatever action is necessary to stabilize such a situation. You may shut down the scanner with the EMERGENCY POWER OFF button or, if you prefer, simply leave everything alone and let BIC staff or the emergency services deal with it. If it is “The Big One” you will likely have other things on your mind than whether or not the scanner should be turned off. Your prime concern is your safety and the safety of your subject, and a speedy evacuation to the EAA.

8. Security:

8.1 The upper floors of Li Ka Shing Center have had several thefts, almost all of which came about because a thief followed someone into the main building.
elevator (not the BIC elevator) and rode unchallenged to an area that genuine LKS occupants consider to be secure. In these “secure areas” it is common for approved building occupants to leave laptops, phones, backpacks and other valuables unattended, so once a thief gained access there were multiple easy targets.

In Section 5.3 it was emphasized that nobody is allowed into the BIC secure zone - designated Zone II - unless accompanied by someone with approved access. To reiterate: Do not allow unsupervised BIC access to anyone you do not know for a fact has his/her own BIC card key approval to at least Zone II level. If in doubt, ask for verification and/or insist that a person unknown to you uses his/her own card key to gain access. Do not allow people to follow you into the elevator or down the stairwell without first checking their access status.

Recognize that it can be awkward, embarrassing or frightening to challenge someone who claims to have legitimate access permissions, no matter their appearance. It is beneficial to have a procedure to avoid being followed into the elevator or stairwell, and to rehearse a standard response in the event someone attempts to follow you without your consent.

If the person claims to have legitimate BIC access – they might claim to have lost their card key, for example – then the best response is to ask them to contact BIC staff via the CALL button next to the elevator. Do not permit the unknown person entry to BIC just because they claim to have legitimate access! State calmly and directly: “I do not have permission to let you into the BIC. Please contact BIC staff.”

It is not necessary to get into a discussion with an unknown person. If the person does in fact have legitimate BIC access then their access concerns should be taken up with BIC staff, nobody else.

If an unknown person does not retreat immediately after being challenged, inform them: “This area is under video surveillance. If you do not leave now I will contact the police. Please leave.” At this point it may be best to either proceed into the BIC if you can do so safely, or it may be preferable to head towards the main Li Ka Shing foyer where there are usually more people. You should focus on getting to a safer location before calling the police. Calling the police in the presence of an unknown person should be a last resort because it may antagonize someone seeking to gain unlawful entry. Making a call in the presence of a potential intruder places you and your valuables at higher risk temporarily. Make yourself safe, then call the police.

If you think that someone is attempting to follow you into BIC without permission, try to discontinue your entry, e.g. by walking past the BIC elevator to a public area that is likely to be occupied by other people. You could wait until the unknown person leaves the vicinity, or perhaps find someone to accompany you back to the BIC entrance.
Note that there are no false alarms in such situations! Nobody with legitimate BIC access should try to coerce someone else into granting BIC access, ever. Thus, you should assume that an unknown person has nefarious intent and UCPD should follow up.

Finally, note that an intruder may try to gain access when you are exiting the BIC. The elevator requires a second card key swipe to activate, so this route of illicit entry is not a concern as you exit. However, the stairwell might be penetrated if you do not assure the door is closed behind you. Neither of the stairwell exit doors on the ground floor have windows for you to check your surroundings before you exit, so use these doors cautiously. Before fully opening the door to exit, open the door a small amount to check that nobody is loitering. Then exit swiftly. Once through, make sure you close the door securely behind you. Note that the stairwell door to the outside of the building is more vulnerable to someone trying to enter as you exit, particularly after hours. The safer option is to use the door to the lobby, where you have a window to the outside, then use the LKS outer glass door. Remember there are also other exits from LKS: one on the same level as the BIC access, and the main entrance one level up.

8.2 There have been several well-publicized violent incidents on university campuses and elsewhere over the past few years. Bomb threats, almost all of them hoaxes, have also been reported. While these threats are unlikely, it is prudent to know how you should react in the event you encounter a suspicious package, a suspicious person, or if a threat is announced in or near BIC.

If you find a suspicious-looking package or container, or you encounter a person who is acting suspiciously, try to move to a safe area and call UCPD on 911 immediately. Do not activate the fire alarm. Instead, act upon the instructions of the dispatcher, and remain in a safe place until told to relocate by emergency personnel.

If you receive a bomb threat, either in person or over the phone, try to stay calm. Try to retain as much information as you can (writing the information down if the threat is telephoned) to forward to the police when you are able to contact them.

Try to call UCPD on 911 as soon as practicable. If the threat comes from a person within BIC, try to take sanctuary in a lockable room – only scanner users and BIC staff have card keys to activate locked doors – and then call 911. If you find yourself in a room unable to make a call, stay put until you are sure that the threat has been removed, e.g. because you hear emergency responders outside.

The UCPD offers advice on surviving targeted violence. While not mandatory for this course, it is a very good idea to review this website: https://ucpd.berkeley.edu/administration/case-emergency/tools-survive-targeted-violence. The video on this site offers advice on what to do in the event of an active shooter scenario. In the case of a campus-wide lockdown, remaining inside BIC may be your safest option. Access to BIC requires card key access (two separate swipes). Inside BIC, there are other places to enhance your
security, including the BIC staff space and staff offices (if you have access to these), the TMS and testing rooms, the bathrooms and, of course, Zones III and IV containing the MRI scanners.

8.3 If there is an explosion within BIC, immediately evacuate using the stairs and assemble outside at the EAA. Do not activate light switches or operate any electrical equipment while you evacuate. However, if the explosion has created smoke and/or fire and the fire alarm hasn't already activated, you should pull the fire alarm as you evacuate. Having evacuated, seek more information from one of the sources listed in section 1.2.