Brain Imaging Center, Li Ka Shing:

Safety Training Course and Standard Operating Procedures

Introduction:

The purpose of this course is to familiarize you with the hazards found in the Brain Imaging Center, and to educate you on procedures in the even 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 their guests and visitors who enter 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 attended a safety training course and read this syllabus you will be prepared to take the safety training quiz. A passing grade is required in order to attain card key access to the BIC. (Access to the 3 T suite is restricted to qualified scanner operators only.) Further information on scanner access policies, user 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 space in BIC. Please contact the BIC manager for information on obtaining a copy of the BEP.
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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
redbush@berkeley.edu

Ben Inglis, Alternate BIC Safety Officer & BIC Manager:

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

Mark D'Esposito, BIC Director:

Office - (510) 642-2839, Cell - (510) 551-3916
despo@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)

City of Berkeley emergency radio station:

1610 AM

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 (email or text) alerts from the WarnMe emergency alert service:

https://warnme.berkeley.edu.

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) operator room is number B100E. The magnet room is number B100EA. (See section 1.8 for a BIC floorplan.)

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

1.5  In an emergency, use the 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. It is recommended that all BIC users have the UC Police Department emergency number programmed into your cellphone.
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, 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 liability.

1.7 The LKS fire alarm is a loud horn 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:
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, adjacent to the 3 T MRI equipment room (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 and Li Ka Shing Halls.

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, next to the BIC elevator (at the foot of the entry/exit stair well) to await emergency responders. (The DWA isn’t yet signposted, a sign is supposedly on order.)

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 The magnet and operator rooms are designed to have emergency lighting, which should enable (perhaps after a brief outage or a flicker) once a backup generator comes online. 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 to see in the magnet room, don’t carry the flashlight inside because it has magnetic batteries! (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 the subject from the magnet manually, e.g. 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. (The scanner restart procedure is covered in the user training syllabus.)

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 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 EMERG POWER OFF button for any reason, you will need to contact either Rick Redfern or Ben Inglis to have the scanner turned back on. You must notify BIC staff immediately because the magnet refrigeration unit should not be left off for an extended period of time. The magnet is liable to drift, which affects performance, and there is an increasing risk of the magnet quenching if the refrigeration is off for more than a couple of days.

2.4 The gradient set is 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 shut the scanner down using the EMERG 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 EMERG POWER OFF button.

3. Fire hazards:

3.1 The most likely ignition sources in the BIC are: (i) electrical 'shorts', including those that can happen within the scanner; (ii) items brought into the operator’s room by users, subjects and visitors (e.g. cigarette lighters); and (iii) lab equipment placed too close to incandescent light bulbs.

3.2 A fire alarm is located in front of the BIC elevator, next to the entry/exit stair well. There is an additional alarm in the emergency exit corridor beyond the alarmed doors adjacent to the 3 T equipment room. (See the floorplan in Section 1.8.) Smoke detectors located in air-conditioning ducts throughout the BIC should activate the fire alarm automatically, but you should know the location of the alarms just in case.

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 by the smoke, you should recover a subject from the scanner and evacuate immediately, as described in sections 1.7 and 1.8. Activate the 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 fire alarm has activated automatically then you may choose whether it is safe to attempt to fight the 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 the magnet room or 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 EMERG POWER OFF buttons. However, your main focus should be raising the alarm and evacuating the BIC.

3.4 If the fire is small, it is safe for you to do so, and 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 the magnet room and in the operator's room.

If the fire seems to be located inside the magnet 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 may not help; the fire may be concealed behind a cover that prevents the fire-retarding agents from working.

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 VERY COLD 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 minus 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 been 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, lungs, etc. Just in case, then, it is safest 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 figure out the source of the noise or the shaking.

If you think the magnet is quenching you should commence evacuation immediately. 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 and to allow fresh air in. 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 has leaked 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, additional oxygen sensors have been installed in the 3 T suite; the unit (with alarm) is located in the 3 T operator room while the sensor is sampling magnet room air. In the event of a low oxygen alarm you should immediately open both the operator room and magnet room doors and evacuate as if a quench is occurring. Contact BIC staff and do not return to the 3 T suite until instructed that it is safe to do so.

5. Magnetic field hazards:

5.1 Nobody shall enter a magnetic field region greater than 5 Gauss (G) without first having been thoroughly checked for magnetic items and screened for any health hazards associated with high magnetic fields. In particular, 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. 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 doesn’t project into the operator room. However, at the rear of the magnet the 5 G contour falls inside the equipment room.

To ensure safe operation and screening, BIC follows the zoning recommended by the American College of Radiology. Zone restrictions are given in section 5.5.
Because the magnet is 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 The BIC is categorized into four zones, as indicated on the floorplan below:

NOTE: the magnet position and 5 G contour are incorrectly marked on this plan! (See the description in the previous section.)

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Zone I is a conceptual zone that encompasses the outside world - everything outside of the BIC elevator and entry stair well. Once inside BIC space you are in Zone II or higher 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 in Zone II 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.

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. Research subjects must be screened while in Zone II before being allowed 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 the 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 of Zones III and IV.

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

Zone IV – 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 screened for MR contraindications and who are completely free of all magnetic objects on their person.

Doorways in BIC are marked with the zone designation for the room beyond the door, i.e. the zone you are about to enter. At the magnet room door there is also a low red gate that indicates that you are entering Zone IV. It is just a reminder barrier, a last chance to ensure that you and your subject really are fully screened.

5.3 Any iron-containing object, including all types of steel (even ‘surgical-grade’ stainless steel), should be considered to be magnetic. Certain other metals, like nickel, also exhibit "ferromagnetism." Most batteries contain magnetic components, for example.
Magnetic objects commonly found in the lab, or on people entering the lab, include: flashlights, cellphones, work tools, scissors, ring binders, sunglasses, paper clips, calculators, keys, chairs, brooms, shoes (their rivets), 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 ferrous metal in them, unless they are specifically designed to be MR safe.

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 room are actually MR compatible. Just in case, however, it is forbidden to take ANY wheeled chair into the magnet room, whether it is supposedly MR compatible or not. A 100% plastic step stool is kept in the magnet room for subjects who have trouble getting on and off the patient bed. It can be used as a seat by persons accompanying a subject for a scan. (See the subject screening procedures in the user training documents for specific procedures on screening accompanying persons.) On no account should any other stool or chair be taken into the magnet room.

When a magnetic object encounters a magnetic field it will experience two types of motion. First, it will try to orient itself such that its longest magnetic axis is parallel to the field direction. Second, if it experiences a field gradient the object will tend to move towards the high field region, i.e. it will move towards the center of the magnet. It will continue moving - and accelerating - 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 geometry. 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 center and continue towards the magnet rear, even exiting the rear of the magnet briefly before being sucked back in!

When the object finally comes to rest - somewhere close to the geometric center if the object is small enough to enter the magnet bore - the force it exerts can be vast, again dependent on the mass of ferromagnetic material. People have been killed after being struck or crushed by a magnetic object attracted onto an MRI magnet. 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, this would essentially be equivalent to having a car fall on you. Serious injury or death is all but assured.
You should also be aware of the effects of the magnetic field on other equipment. Most electronics don't like 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 well be expensive. Leave your laptop, digital camera, wallet, watch, keys, spare change, cellphone and sunglasses in the screening room.

5.4 Non-magnetic 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). As a point of safety, then, all objects in the lab should be considered to be magnetic unless they can be positively determined to be non-magnetic (e.g. 100% plastic) or are specially designed to be MR-safe. If in doubt, keep it out!

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 small permanent magnet, for example. Therefore, testing an object for magnetism with a permanent magnet is not considered an acceptable test. In general, then, nothing should be taken into the magnet room without the supervision and permission of BIC staff.

When a non-magnetic metallic object (e.g. a copper RF coil, or an aluminum ball) 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 force generated by the electric ring currents set up in the conductor because of its motion. (Metals are excellent electrical conductors.) The electric current, and hence the magnetic force, 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 field will minimize the force. When the non-magnetic object is stationary there is no magnetic force on it, in stark contrast to a (ferro)magnetic object.

5.5 Nobody may be permitted from entering a field of greater than 5 Gauss without proper screening for internal health hazards. 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 carefully but quickly evaluated before any action is taken.

First of all, determine whether there is any threat of serious injury or death caused by the object. If there is, immediately push the magnet quench button to discharge the magnetic field. 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.

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 ten or fifteen seconds. Once you have rescued the subject from the magnet you should evacuate the building 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 injury, take a few moments to consider your options. If an object is stuck to the outside of the magnet and is not impacting the subject or preventing his egress, determine whether you can remove your subject from the magnet, then call BIC staff for assistance. But do not do anything that places the subject at further risk! Do NOT use the electronic patient bed controls if you think that moving the bed might dislodge the stuck object. Either retrieve your subject by his feet, or quench the magnet if there is no way to retrieve your subject safely.

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 to the effect 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! You may be able to pull the subject along the patient table without moving the table or the RF coil, for example. If the object is impacting the head RF coil, pull the subject out by his feet instead of using the patient bed controls. That leaves the head RF coil – and the magnetic object – where it is; at rest and at equilibrium.

Why not just push the quench button whenever anything gets sucked into the magnet? You might well ask. Time and money! If all went well, it would take tens of thousands of dollars and a couple of weeks to bring the magnet back online. 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. Never try to move 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 with time (called the rate, dB/dt) 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 find that your senses get used to being around the magnet.
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 extensive 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 out for from a 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 at the BIC 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 as early in the screening process as possible, well before the day of the scan. Even so, you must also screen your subject when he/she arrives at the BIC, to assure that he/she is still safe to be scanned.

On the day of the scan, subjects should be screened in room B100C, the “spare” 3 T operator room. Ask the subject to remove all external metallic objects as far as possible. Double check for jewelry, especially pierced jewelry, hair clips, keys and other 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 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 the 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.

Women who are or who may be pregnant must not be scanned. Insufficient research has been conducted on the potential hazard of high-field MRI to warrant the risk. 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.

6.3 When the scanner is acquiring images, the radiofrequency oscillating (123 MHz) magnetic field generated by the transmission RF coil causes a low amount of energy, as heat, to be deposited into a subject lying in the magnet. On the Siemens 3 T, 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 normal tissue perfusion, 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 on the Siemens 3 T, 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. This is a primary concern for transmit/receive surface coils, and at present the 3 T has none of these coils. If ever such coils are introduced, their use will involve specific training as part of the operator training syllabus.

Finally, if you wish to scan very young or very old subjects, 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 ultra-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 RF signals being excited and detected. All imaging sequences use pulsed gradients. However, fast imaging sequences, such as EPI, represent the largest hazard to the subject because the gradients are very large and they are pulsed very quickly. Consider a gradient of 2 G/cm switched on in 200 microseconds; typical values in an EPI scan. 2 G/cm is equivalent to 0.02 T/m. The rate of change of field with time, dB/dt, will be 25 T/s a mere 25 cm from the magnet isocenter, i.e. from the
center of the subject's head. 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 currents inside the subject's body. Fortunately, the current threshold necessary to generate such effects as peripheral nerve stimulation (PNS) is fairly high relative to the size of the currents being induced, and to date most reports have been limited to discomfort, tingling, muscle twitches and, very rarely, visual flashes (magneto-phosphenes being triggered in the eye).

As with RF heating, the scanner monitors the gradient switching and makes estimates of the likely limit that might cause PNS. Based on the subject's weight, approximate body dimensions are estimated and used to determine whether the scan will trigger stimulation or not. If the estimate is above some 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 subject's conductivity and geometry. A subject might still experience localized peripheral nerve twitching.

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 the subject experiences discomfort during the scan then he 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. (This is known as Flemming's Left Hand Rule.) 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. (If the coil was moved away from the magnet center and then pulsed it would very likely move!)

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 simply because the whole coil is "potted"
in a tough epoxy resin. The sum total of all these attempts at motion are the familiar, and extremely loud, “banging” or “pinging” sounds that emanate from the magnet during a scan. EPI can generate noise as loud as 120 dB, necessitating certain operating procedures to prevent damage to hearing in subjects and operators alike.

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 earphones as well as earplugs. These allow easy communication with your subject as well as several dB of additional scanner noise protection. If it is not possible to fit earphones inside the RF coil (e.g. because you’re using the 32-channel head 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 experiment, 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 doorframe, for cover and brace yourself against the object until the shaking stops. Bear in mind that the wall between the 3 T operator room (room B100E) and the magnet room (B100EA) is a seismic shear wall; thus, any building motion is likely (but not necessarily) to
be larger away from this wall. Likewise, the 3 T magnet is bolted to the concrete floor and the 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.

If there is no light when the shaking stops, follow the blackout procedures in section 2.2 and remove the subject from the magnet manually, then evacuate. If you hear any sort of rushing noise from the magnet, assume it is 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.

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 and/or the peripherals or, if you prefer, simply leave the 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 peripheral equipment should be turned off. Your prime concern is your safety and the safety of your subject, and a speedy evacuation to the EAA.

8. Bomb threats or explosions:

8.1 There have been several well-publicized incidents on university campuses over the past few years. Bomb threats, almost all of them hoaxes, have also been reported a number of times. While these threats are extremely unlikely, it is prudent to know how you should react in the event you encounter a suspicious package, a suspicious person, or 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 from a land phone 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, attempt 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.

8.2 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.