Magnetic resonance imaging (MRI) has become a mainstay of diagnostic imaging. When properly used, it is very safe and effective. Safety concerns do exist, however, with each type of magnetic field associated with an MR system: the static field \( B_0 \), the radiofrequency field \( B_1 \), and the gradient magnetic fields used for spatial encoding. In this chapter, we focus on issues relating to the static magnetic field \( B_0 \).

There are two types of forces exerted on a ferrous object when brought in proximity to an MR magnet: rotational and translational. The rotational force (torque) is that which causes a ferrous object to turn and align with the direction of the main magnetic field \( B_0 \). Rotational forces are strongest at the isocenter of the magnet. Translational forces are those that cause a ferrous object to be pulled toward the magnet isocenter. Translational forces are actually near zero at the isocenter because translational forces are felt when a ferrous object is in a magnetic field that changes in strength over distance. MRI requires a homogeneous magnetic field over the entire field of view and, thus, there is little translational force within the bore of a magnet. However, as one approaches an MR system, entering from the door of the scanner, the field strength begins to increase. The closer one gets to the magnet, the more rapidly the magnetic field strength increases. As magnetic field strength increases, so does the attractive force on ferrous objects. Most horizontal field (cylindrical) MR systems today are magnetically shielded to bring this fringe field closer to the magnet for sitting purposes. As a result, the magnetic field changes very rapidly as one gets closer to the magnet. Bringing a ferrous object into the room is extremely dangerous and should not be done. Many times, once one feels the pull of the magnetic field, it is too late. Fig. 2.1 shows the result of a floor buffer that was inadvertently brought into an MR scan room. There have been cases of injury and death resulting from ferrous oxygen tanks being brought into a scan room. Non-MR compatible wheelchairs represent an important additional example of an object that should never be brought into an MR scan room.

Vertical field (some low-field or so-called open MR) systems are not safer with regard to translational forces. Even though the magnetic field at the isocenter may be lower than the field strength of horizontal field...
(cylindrical) magnets, the change in the fringe field is actually very great near the magnet poles, going from near zero to the maximum in just a meter or two. The same precautions that one follows for high-field (1.5 or 3 T) cylindrical systems should be followed regardless of the MR system field strength or orientation. It should also be noted that, for the vast majority of magnets, the magnetic field is always “on” (this is true of both superconducting and permanent magnets) and cannot be turned off other than by quenching the system. For all types of MR systems, access by non-MR personnel should be restricted, and warning signs, stating that the magnet is always on, are advocated.

The presence of implants and magnetically and/or electrically activated devices can pose serious hazards for anyone with such an implant or device entering the scan room. For example, some intracranial aneurysm clips (used in the distant past) represent a contraindication to MR due to the force that can be exerted, leading to displacement and potentially death. An MR scan is contraindicated in a patient with an aneurysm clip, such as that illustrated (arrow) on CT in Fig. 2.2, for which the exact type cannot be documented. Screening for an MR exam by necessity must be in-depth and thorough. Top contraindications (among a long list) include metal within the globe (eye), a ferromagnetic aneurysm clip, or a cardiac pacemaker (see Chapter 3). Screening must cover any metal or implants within the body. Anyone entering the scan room (or going beyond the 5-gauss line) must be screened by trained MR personnel. This includes not only the patient but also any family members or support personnel. Most orthopedic implants, fortunately, are made from nonferromagnetic materials and are thus safe for MR.

If the patient has some type of implant or device, it should be positively identified so that the physician can determine if it is MR safe or if there is a significant risk such that the patient should be excluded from entering the MR scan room. It is the ultimate responsibility of the MR radiologist/physician to determine if a patient can safely undergo an MR procedure. With the advent of higher field MR systems (3 and 7 T), it is important to remember that implants and/or devices that have been found safe at 1.5 T are not necessarily safe for imaging at higher fields. However, most such implants and devices are indeed safe at 3 T. It should be noted, regardless, that rotational forces on a ferromagnetic object inside a 3 T magnet increase by a factor of 4 compared with those of a 1.5 T magnet and that translational forces approximately triple. Up-to-date information about implant safety and testing can be found at www.MRIsafety.com.

![Fig. 2.2](image-url)