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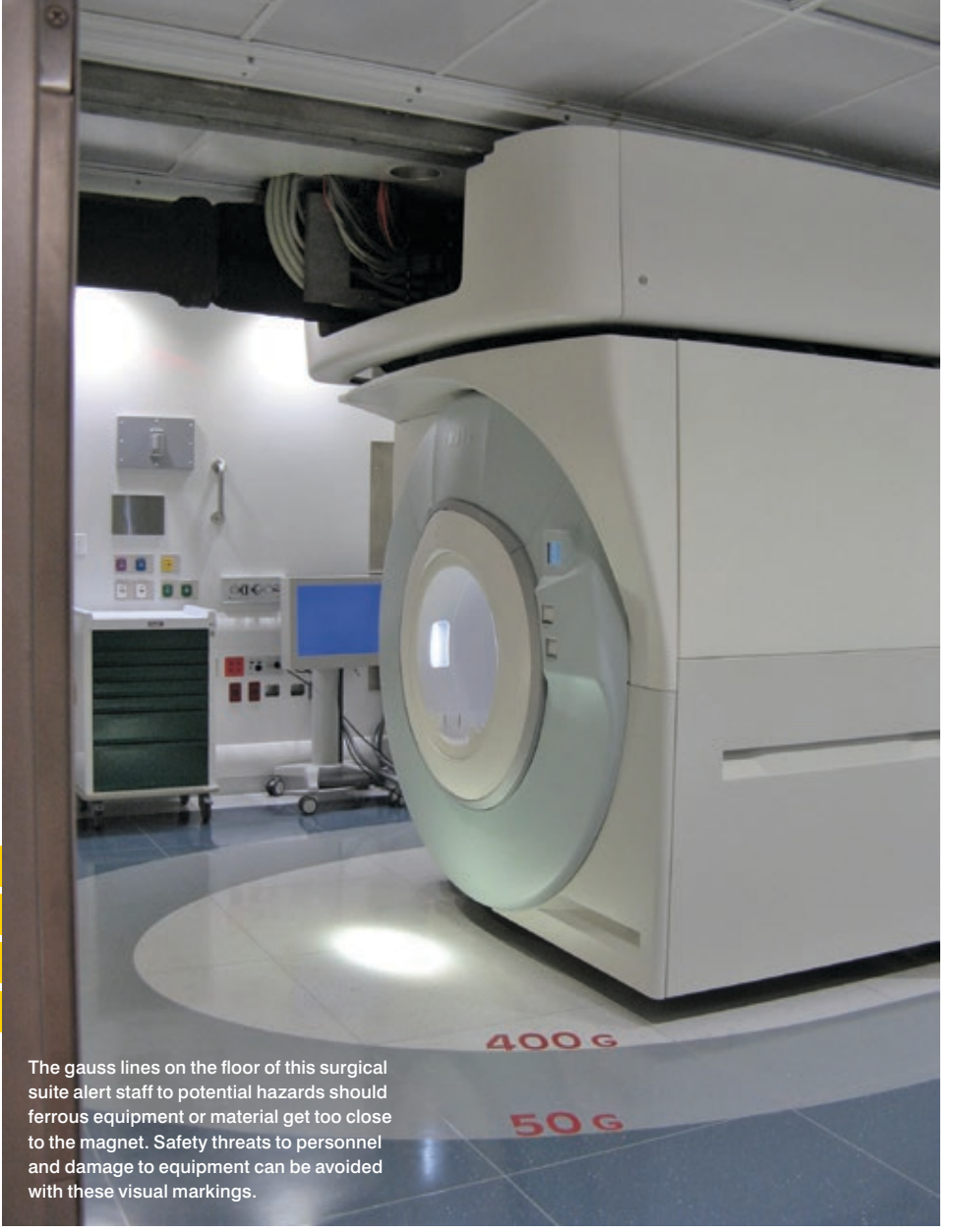
Strategies for designing an efficient intra-operative magnetic resonance imaging space



The gauss lines on the floor of this surgical suite alert staff to potential hazards should ferrous equipment or material get too close to the magnet. Safety threats to personnel and damage to equipment can be avoided with these visual markings.

By Jim Mueth and Joe Weibler

Intra-operative magnetic resonance imaging is quickly becoming the leading technology in the integration of various radiologic modalities for medical procedures. iMRI refers to the use of an MRI magnet during a surgical or treatment procedure — either a moving magnet brought into the theater or by moving the patient to the room containing the magnet. In both cases, imaging of precise locations is performed prior to, during and after the surgical or treatment procedure. This allows for removal or treatment of diseased tissue while preventing damage to healthy tissue. The real-time availability of the high-resolution MR images is improving patient outcomes in neurosurgery, as well as cardiovascular and radiation oncology.

When a hospital is considering an iMRI suite, defining the types of procedures and the volume that will be supported by the iMRI is the first step. This provides the basis for the design criteria. Considerations for cost-effective design include:

MOVING OR STATIONARY MAGNET SYSTEM CONFIGURATION

iMRI can take on multiple configurations starting with either a moveable or stationary magnet system. A moveable magnet system offers the optimal procedure scenario in that the patient remains stationary throughout the surgery or treatment. This provides the doctor with the assurance that the treatment area remains in the exact location the image indicates and offers the highest likelihood that the procedure will be successful the first time and not require additional surgeries.

A stationary magnet system offers better procedural control for safety as the MRI environment is primarily static. The strong magnetic field remains in its own room so it is less susceptible to human error that may result in ferrous materials being introduced that could put the patient, staff or equipment in jeopardy. This system requires less radio frequency shielding, which reduces cost. The potential for poor image quality from possible RF-shield degradation is lower since only the magnet room requires RF shielding. These advantages come with key disadvantages in the undesired movement of a surgically open and sterile patient, as well as a potential shift in tissue.

VIBRATION AND ELECTROMAGNETIC INTERFERENCE

Designing and installing a moveable magnet system is a more complex endeavor than a stationary MRI, but both present unique challenges. For surgical theaters, a primary issue is how to structurally support the weight of an MRI, as many operating rooms are located above the ground floor. Both structural vibration and electromagnetic interference are always concerns

when siting an MRI and must be considered when evaluating potential locations.

An EMI and vibration survey must be performed in the proposed location to confirm the space is within the selected magnet specifications. Elevators and electrical transformers are top EMI contributors, while air handling systems and vehicles in parking garages can cause vibration issues. Most issues can be resolved through EMI shielding, active cancellation, vibration dampening or relocation of the source. All of these will add to the overall project cost so advance planning that takes these items into account upfront will minimize the budget impact later.

As modalities and devices are added, the planning complexity grows. RF and radiation shielding must be in place per equipment specifications. Devices to be used in rooms with the magnet must be MRI compatible and MRI safe. Protocols must be in place to move them to an acceptable location so as not to interfere with the imaging or become a projectile in the magnetic field.

ACOUSTIC AND MAGNET NOISE

Acoustic considerations are an important factor in the overall suite design since the MRI magnet can be loud during scan sequences. If the magnet bay is also intended to function as a clinical imaging suite when not needed during surgery, then the OR area needs to be protected from the acoustic noise generated during MRI scans. This allows both areas to be used simultaneously for more efficient use of the hospital resources. While there is a fair amount of ambient noise present in an OR, sudden and loud noise from an MRI scan could startle people working in the OR.

PATIENT AND PERSONNEL SAFETY

Patient safety is the primary concern when designing an iMRI. Maintaining a sterile environment is crucial for the patient. Typically, a positive air pressure is maintained in the OR to minimize the possibility of airborne pathogens entering the area. With the larger doors needed for the intra-operative environment, air handling in these areas may require additional planning to ensure proper air pressure in the OR and adjacent areas. Since minimizing or eliminating pathogens is a primary concern in an OR environment, the RF-shielded door designs used in the iMRI area need to have surfaces and thresholds that may be easily cleaned and minimize fluid/dirt/dust collection points.

The large magnet bay doors are generally intended to provide magnet safety for the OR personnel and others in the event of an emergency. In the unlikely event of a fire, for example, the magnet bay doors provide a safety barrier for protecting people who need to be in the same area as the MRI, but may not have experience working around an MRI magnet. Specialized control systems should be used to provide personnel safety functionality.

A marriage of modalities is shown in this surgical suite. The patient remains stationary while a C-Arm scan and MRI may be conveniently moved to provide images in real-time during surgical procedures and treatments.

PREVENTIVE MAINTENANCE

Key to the continued successful use of an iMRI theater is the assurance that the equipment and supporting technology are always working at top performance levels. Preventive maintenance should be scheduled and performed on a regular basis. As with any MRI, periodic maintenance is required to check and fill helium levels, examine cabling for wear and damage, review image quality through internal diagnostic testing and checking coils and patient tables to ensure they are functioning as expected and are in good condition.

The RF-shielding system integral to obtaining the highest quality images is another important component requiring maintenance. iMRI by design requires a higher level of RF-shielding technology to allow for the best operational flow of patients and staff to access the MRI machine. RF doors require frequent cleaning and operational maintenance to ensure continued RF integrity and functional performance.

Simulation of a full procedure should be made periodically to confirm everything is working as a system.

Researchers and surgeons are continually expanding the use of high-quality iMRI images. Successfully implementing an iMRI suite requires upfront planning by experts to address all aspects of these complex projects. ■

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