

# Hold Still: Mitigating Noise and Vibration From MRIs

By Benjamin C. Davenny and Jeffrey A. Zapfe

Magnetic resonance imaging (MRI) devices have become an important part of medical diagnosis. Demands on the quality and resolution of images have increased, requiring stronger magnetic fields and extreme gradient sequences that have generally increased both noise emissions from the MRI and the vibration sensitivity of the MRI. In past years, MRIs and other vibration-sensitive equipment were often located in the building basement on a grade-supported slab. More and more, owing to workflow, patient needs and space efficiency considerations, this equipment is being moved up in the building onto structural floors. In some cases, financial pressures are encouraging health systems to repurpose office or other nonclinical space and use it for outpatient medical diagnosis. The repurposed space is often not well-suited for the installation of an MRI, particularly when it comes to noise transmission.

## Vibration Sensitivity

MRIs are sensitive devices that can be adversely affected by floor vibration. Allowable floor vibration limits for MRIs are typically about 10 times lower than the threshold of human perception; hence, the concern related to vibrations that people cannot even feel.

One of the first steps in evaluating the suitability of a new space is the assessment of floor vibration. Possible sources of offending vibration include local road and railway traffic, building mechanical systems and footfalls (people walking). Above-grade structural floors are susceptible to vibration generated by footfalls, particularly when major traffic corridors are near the MRI bay. The potential footfall vibration problem is even more acute if the structure was not designed for MRI use but was designed as a general office area, for example. The structural modifications needed to support the large mass of the MRI may be sufficient to alleviate footfall vibration issues, but this is not always the case.

## How MRIs Produce Noise

Anyone who has ever been the subject of an MRI scan knows that MRIs are loud. The noise generation is a result of the excitation of the gradient coils during the imaging process. Parameters relevant to imaging are the repetition time (TR), echo time (TE), slice thickness and field of view. The types and noise levels of scans chosen for imaging may depend on the type of facility in which the MRI is located. Some scans are louder than others, but generally at some point in the scanning process, there will be at least one scan that produces a particularly loud and annoying sound.

## MRI Noise Control

Inside the MRI bore, where MRI manufacturers typically provide noise data, the MRI noise levels can be as high as



120 dBA. For reference, 120 dBA has been measured at rock concerts, 110 dBA is the volume of a motorcycle a few feet away and 100 dBA is the sound level of a car horn a few feet away. The sound falls off in loudness as one moves away from the bore. Near the walls of the MRI room, the typical levels are in the range of 95 dBA to 105 dBA. The sound at the perimeter is important because this is the sound that can propagate into adjacent spaces.

As important as the loudness of the sound is its frequency. Most MRI noise occurs in the mid frequencies between 500 Hz and 2,000 Hz. The transmission loss (sound attenuation) of typical floor-ceiling construction is about 50 dB at those frequencies. This means one can expect about 45 dBA to 55 dBA of MRI noise to be transmitted into the spaces above and below the MRI room. Even at these levels the MRI noise level can be highly tonal and extremely annoying. To further reduce the transmission of MRI noise to floors below, gypsum board ceilings can be installed between the deck and the finished ceiling, either between or below the beams. These types of constructions can provide another 10 dBA to 20 dBA of attenuation.

Appropriate wall constructions will depend on the adjacencies. Ideally, corridors, equipment or support spaces would be located around a MRI room. Layouts like this provide at least two well-spaced walls between the MRI room and sensitive adjacencies. In cases where a noise-sensitive space is on the other side of the wall, more substantial wall constructions will likely be needed.

The isolation to the control room is determined by the window, door and cable pass-throughs. The radio frequency (RF) doors and windows are typically available with Sound Transmission Class (STC) ratings up to 44. When choosing these windows and doors, openings in the control room wall for cable pass-throughs and waveguides must be considered, as these will control the sound isolation of this wall.

### Typical MRI Room Enclosures

MRI rooms are always constructed within a RF enclosure to protect the MRI from outside RF interference that can adversely affect the operation of the device and the quality of the image. Walls around MRI rooms are typically constructed using a double wall arrangement consisting of an outer parent wall and an inner enclosure wall. The parent wall is a metal stud wall with gypsum board on both sides. The enclosure wall typically has copper shielding on the cavity side and gypsum board on the room side. The enclosure walls terminate at the enclosure ceiling framing, which consists of a framework with copper above. Unless otherwise specified, an acoustical ceiling tile grid is suspended directly from this framework. If more sound isolation between the MRI room and the floor above is required, gypsum board can be attached to the underside of the enclosure ceiling framing. To further increase the sound isolation, neoprene hangers can be used to more effectively acoustically isolate the enclosure ceiling from the structure above.

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Duct paths in and around the MRI room also need to be considered. Noise can enter the ducts through the air supply/exhaust openings in the MRI room and travel to nearby spaces served by the same duct system. (This is also known as duct “cross talk.”) Duct systems serving MRIs should be separated as much as possible from systems serving other occupied spaces, especially those spaces unrelated to the MRI use. Duct silencers at the penetrations of MRI rooms can be used to reduce the cross-talk transmission of MRI noise.

### Structure-Borne Noise

MRIs also produce a considerable amount of floor vibration during scanning. These vibrations result from the dynamic forces that are transmitted to the floor through the MRI feet. Once the vibrations are within the structure, they can travel efficiently to other parts of the

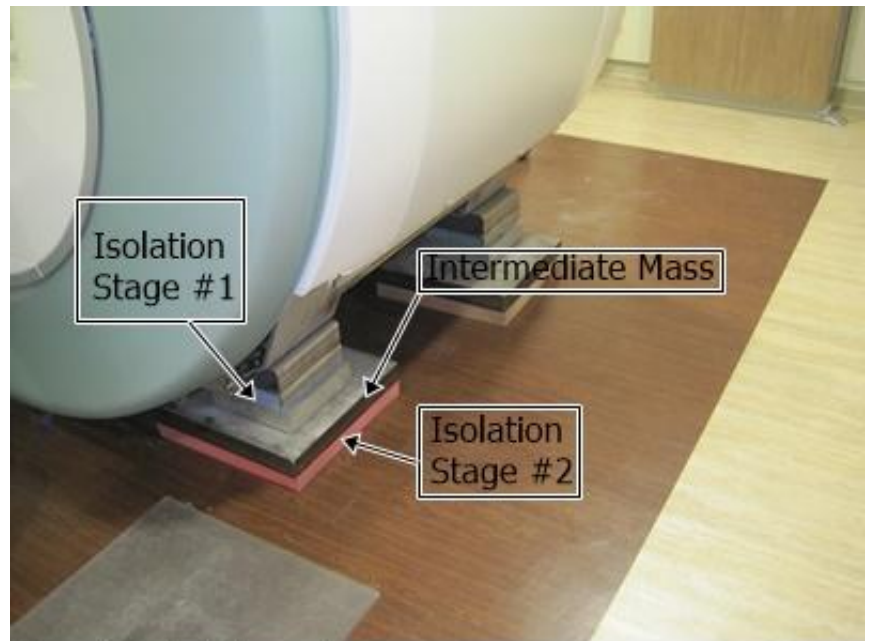
building. As they travel, the vibrations excite floor, wall and ceiling elements, which then radiate noise much like giant loudspeakers. It is not uncommon to be able to hear an MRI scan many offices away from the MRI room. It is important to note that this particular sound is produced by the vibration in the structure; it is not related to the airborne sound that one can hear inside the MRI room.

Structure-borne sound is a major consideration in the design of comprehensive sound isolation for MRI rooms. The best airborne sound isolation schemes can be rendered ineffective by flanking sound due to structure-borne vibration.

The best control of structure-borne sound is accomplished by vibration isolation at the MRI feet. Vibration isolation effectively limits the amount of vibration that can get into the floor in the first place. Modern MRIs are typically

installed atop some form of vibration isolation, usually an elastomeric pad. Some manufacturers have used helical metal springs as isolators. Unfortunately, coil springs have internal high-frequency resonances that are lightly damped and consequently defeat the isolation effectiveness at particular frequencies. This can be problematic when the resonances coincide with the MRI excitation frequencies. Coil spring isolators should be avoided if possible, and used very carefully if necessary.

Single-pad or one-stage isolation systems are usually sufficient for MRIs located on grade-supported slabs. On above-grade floors, particularly ones with sensitive adjacencies below the MRI, a single-stage system will likely not be sufficient — a more advanced two-stage isolation system should be considered. A two-stage isolation system consists of two isolation pads separated by



Two-stage isolation system.

a heavy intermediate mass (usually a stainless-steel plate). The intermediate mass is a critical part of the isolation system because it allows the two springs to act independently. A well-designed two-stage system can provide twice as much isolation as a single stage isolator (40 dB compared to 20 dB, for example).

One other potential path for structure-borne vibration is the MRI quench pipe, which allows helium gas to escape in the event of an emergency. The quench pipe should be isolated from the building structure with neoprene hangers.

### Advances in Noise Reduction

Patients have complained about the high levels of noise inside the MRI bore. Excessive noise can affect the results of brain images because it activates regions of the brain associated with hearing. MRI manufacturers are working to reduce noise from MRIs through changes to hardware and software. For example, GE has developed Silent Scan to reduce noise, Siemens is marketing its technology called Silent Suite and Toshiba has developed Pianissimo. Hardware changes involve newer mounts for the gradient coils to reduce vibration transmission. The largest noise reductions are achieved with quieter scans that involve steadier, gradually changing gradient fields rather than rapid gradient switching. Some manufacturers have suggested that these quieter scans will reduce MRI noise down to the ambient noise of the MRI room, around 60 dBA to 70 dBA, which is similar to the level of conversation at about 3 feet.

Strategies exist for control of noise transmission from MRIs to nearby spaces in different types of facilities. Treating an above-grade MRI for noise transmission takes more effort than treating an MRI on slab on grade, but it is possible. Advances in MRI technology may render MRI rooms no louder than X-ray rooms. Until then, pay close attention to details for your MRI room construction.

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