Weighing the benefits and risks of magnetic resonance scanning of patients with implanted cardiovascular devices

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Magnetic resonance (MR) and magnetic resonance angiography (MRA) are increasingly utilized imaging modalities in clinical practice. At the same time, an increasing number of patients are being treated with implantable cardiovascular devices, such as coronary and peripheral stents, embolization coils, IVC filters, aortic endostents, and pacemakers and implantable cardiac defibrillators (ICDs). The performance of MR (and MRA) in patients with metallic devices, particularly cardiovascular devices, has traditionally been approached with great caution. Concerns about device dislodgement, migration or dysfunction have lead many imaging specialists to understandably have concerns about scanning patients with such devices. The clinician is therefore often faced with the difficult issue of trying to assess the risks of MR in such patients versus the benefits of scanning such patients, as well as the timing of such scans after device implantation.

To address this issue, the American Heart Association (AHA) recently commissioned a writing group of experts in the fields of MR imaging, MR physics, MR safety, interventional radiology, general cardiology, and interventional cardiology to systematically review the data and studies on MR safety and cardiovascular devices, and to issue a series of recommendations. This Scientific Statement has recently been published [1].

The risks of MR arise from three basic aspects of scanning [1-4]. Magnetic resonance utilizes extremely powerful static magnetic forces (usually 30,000–60,000 times the Earths magnetic field). This powerful magnetic field has the theoretical potential to move or dislodge an implanted metallic cardiovascular device. Magnetic resonance also involves "pulsing" radiofrequency (RF) energy during the actual scan. If the implanted magnetic device acts as an "antenna", this RF energy has the potential to cause local heating or to conduct electrical currents. Magnetic resonance scanning also involves the use of time-varying magnetic fields (called "gradients") to image the scanned field of interest. These rapidly varying magnetic fields also have the potential to induce electrical currents.

One important determinant of the relative safety of MR scanning is the degree of the devices ferromagnetism. In simplified terms, the degree of ferromagnetism denotes to what extent an object is affected by a magnetic field. Devices are generally classified as nonferromagnetic, weakly ferromagnetic, or ferromagnetic. The risks of scanning also depend in part on whether the device can conduct electrical currents (such as a pacemaker lead) or whether it has components that might be affected by the magnetic fields used in scanning (such as the pacemaker itself). Devices that are found during testing to be nonferromagnetic, do have the potential to conduct electrical current, and have no electronically or magnetically activated components can generally be scanned at any time after implantation. Devices that are labeled after testing as "ferromagnetic" are generally felt not to be safe to scan.

For many devices, testing will reveal that they fall someplace between nonferromagnetic and ferromagnetic. These devices are labeled as "weakly ferromagnetic". There has been considerable controversy regarding when it is "safe" to scan a patient who has been treated with such an implanted device. On the one hand, it is theoretically possible that the forces during an MR examination could lead to movement or dislodgement of the device. On the other hand, however, many implanted cardiovascular devices are firmly embedded or secured against the vascular wall at the time of insertion (such as with the high-pressure deployment of a coronary stent against the coronary wall), and thus should be less apt to move or migrate. It is believed that for some devices, the tissue healing process that occurs after device implantation over the subsequent weeks serves to further anchor the device firmly in place, and thus it has been advocated by some that one wait approximately 6 weeks before MR scanning of certain weakly ferromagnetic devices.

Since many implanted cardiovascular devices are weakly ferromagnetic, how should one weigh the risks and benefits of MR scanning after device implantation? For some devices for

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which there is sufficient data and consensus, it is felt that it could be stated that patients with such devices could undergo MR scanning any time after implantation. This recommendation applies to many currently tested and utilized coronary stents, including some commonly used drug-eluting stents (though the reader should note that some stents used throughout Europe may not yet have been evaluated in a manner similar to those approved for use in the United States). For other weakly ferromagnetic devices in which there is not enough data to make definitive recommendations, the following approach seems most reasonable. This approach emphasizes balancing benefit and risk, and integrates the clinical judgment of the clinicians involved. In the days to weeks after such device implantation, in cases in which there is a clear potential of clinical benefit of scanning the patient at that time (such as acute back pain after trauma), the benefits of MR scanning likely outweigh any risks of the examination, and the MR examination should generally be performed. For patients in whom it makes little difference whether the scan is performed at a given time or weeks later (such as those with chronic back pain for years), it may be reasonable to defer the MR examination until approximately six weeks after devise implantation. The reader should note that this latter recommendation is based both on real and theoretical considerations, and the AHA writing group strove to emphasize that ultimate decisions be based on clinical judgment of benefits and risks.

Based on the above considerations, one can state that nonferromagnetic devices, including most currently used coronary stents, some peripheral stents, some aortic stent grafts, most prosthetic heart valves, some cardiac closure devices, some IVC filters, and most embolization coils, can safely be scanned any time after implantation. Most other cardiovascular devices are weakly ferromagnetic, and the timing of scanning patients should be based on benefit and risk considerations as discussed above.

In contrast to most cardiovascular devices, pacemakers and ICDs merit special consideration [1,5]. Because of the complexity of issues involved with these devices, MR scanning should only be considered when alternate imaging modalities will not provide comparable information, and scanning should only be considered at centers with expertise in MR safety and physics and in electrophysiology. Scanning considerations for patients with pacemakers and ICDs are discussed in detail in the AHA Scientific Statement.

Temporary implanted cardiovascular devices, such as pulmonary artery catheters (such as Swan-Ganz catheters) and temporary transvenous pacing wires, also merit special consideration. Although many such devices contain no ferromagnetic components, they may contain electrically conductive materials, and have the potential to induce thermal injury. Thus, before MR examination, it should be positively determined whether or not the pulmonary artery catheter contains electrically conductive pathways in the catheter. Magnetic resonance scanning of patients with temporary transvenous pacemakers should generally not be performed.

In summary, MR is an excellent and increasingly frequently utilized imaging modality, and as a greater number of patients are treated with implantable cardiovascular devices, issues regarding the safety and timing of MR examination in such patients will more frequently arise. It is important that patients with cardiovascular devices who require MR scanning not be denied such scanning do to unfounded beliefs that patients with cardiovascular devices cannot be scanned. At the same time, it is important that clinicians and imaging experts understand the safety issues involved in scanning such patients. For all devices, the benefits and risks of scanning must be considered on an individual basis; the timing of scanning such patients depends on the degree of ferromagnetism of the device and the clinical indications. Although general recommendations can be made regarding the scanning of devices, the issues regarding testing and safety of devices are actually often quite complex, and beyond the scope of this manuscript. Therefore, in addition to reviewing the AHA Scientific Statement on this issue, clinicians should consult other general sources of MR safety guidance [2,6,7], as well as information specific to the exact device that has been implanted, such as dedicated Web sites [8], reference manuals [4], and the manufacturer's product information.

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